PB81-200552

Annual Report on Irrigation Tailwater Management 1976-1977

California Univ., Davis

Prepared for

Robert S. Kerr Environmental Research Lab.
Ada, OK

May 81

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-81-034c	2. ORD Report	3. RECIPIENT'S ACCESSION NO. PB81 200552
4. TITLE AND SUBTITLE 1976-77 ANNUAL REPORT ON "IRRIGATION TAILWATER MANAGEMENT"		5. REPORT DATE May 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Kenneth K. Tanji, J. W. Biggar, G. L. Homer, R. J. Miller, and W. O. Pruitt		8. PERFORMING ORGANIZATION REPORT NO. 4014
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Land, Air and Water Resources University of California Davis, CA 95616 R		10. PROGRAM ELEMENT NO. 1BB770
		11. CONTRACT/GRANT NO. R-803603
12. SPONSORING AGENCY NAME AND ADDRESS Robert S. Kerr Environmental Research Laboratory Office of Research and Development U. S. Environmental Protection Agency Ada, Oklahoma 74820		13. TYPE OF REPORT AND PERIOD COVERED Annual Report 1976-77
		14. SPONSORING AGENCY CODE EPA/600/15

15. SUPPLEMENTARY NOTES

247 pages, 31 figures, 47 tables, appendices

16. ABSTRACT

This study was undertaken to obtain information and data on irrigation tailwater and other components of irrigation return flows from two representative sites in the Central Valley of California. Extensive data on the quality and quantity of supply and drainage waters were collected for the 1975-77 period from the 664 km^2 Glenn-Coluse Irrigation District and the 113 km Colusa Basin Drain in the Sacramento Valley, and the 1620 km^2 Mendota-Crows Landing Return Flow Group in the west side of the San Joaquin Valley. This annual report presents the data and results determined during the period of March 10, 1976 to March 9, 1977. Publications and reports emanating from the study are presented. Detailed results from the field studies in the San Joaquin and Sacramento Valleys are presented. The appendices provided detailed data from the individual field studies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water resources, irrigation, water quality agricultural economics, drainage, salinity	Irrigation tailwater, tile drainage, tailwater production, irrigation return flows, water management practices, wildlife refuge	68 D

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 247
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

PB81-200552

EPA 600/2-81-034c
May 1981

Water Science and Engineering Paper 4014

IRRIGATION TAILWATER MANAGEMENT

Second-Year Annual Progress Report for EPA Grant No. R 803603-02,
March 10, 1976 to March 9, 1977

Project Investigators: K. K. Tanji, J. W. Biggar, G. L. Horner, R. J. Miller,
and W. O. Pruitt

Project Staff: M. M. Iqbal, A. F. Quek, D. A. Prewitt, W. G. Kinney,
R. J. Schnagl, J. Lyon, J. A. Sellick, R. Fujii,
S. Von Oettingen, D. W. Wolfe, and M. Blenkush

from

Department of Land, Air and Water Resources
Water Science and Engineering Section
University of California, Davis

and

U.S. Department of Agriculture
Economic Research Service, Davis

June, 1977

PRODUCT OF:
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TABLE OF CONTENTS

Chapters		Page
I.	INTRODUCTION AND PROJECT OBJECTIVES	1
II.	ACKNOWLEDGMENTS	4
III.	SCOPE OF REPORT AND SUMMARY	5
IV.	PUBLICATIONS AND REPORTS	9
V.	SAN JOAQUIN VALLEY FIELD STUDIES	66
	A. Mendota-Crows Landing Return Flow Group	66
	B. Broadview Water District	82
	C. Panoche Water District	89
	D. Los Banos Wildlife Area	108
VI.	SACRAMENTO VALLEY FIELD STUDIES	119
	A. Sacramento Valley Return Flow Group	119
	B. Glenn-Colusa Irrigation District	122
	C. Colusa Basin Drain	145
VII.	TOUR OF FIELD STUDY SITES	156
VIII.	APPENDIX TABLES	160

CHAPTER I. INTRODUCTION AND PROJECT OBJECTIVES

In response to national demand for cleaner water, the Federal Water Pollution Control Act was amended by Public Law 92-500 in October, 1972. The objective of the Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The ultimate goal of PL 92-500 is to eliminate the discharge of pollutants into navigable waters by 1985, with an interim goal of achieving, "wherever possible," water quality that is "fishable and swimmable" by July 1, 1983. The Administrator of the U.S. Environmental Protection Agency (EPA) has been given the responsibility to implement and enforce this Act.

As part of PL 92-500, research and development grants are being awarded. This group is one of the recipients investigating irrigation return flows. EPA Grant No. R 803603, Irrigation Tailwater Management, was initiated in March, 1975, for a two-year period. Supplemental financial support was also provided by the California State Water Resources Control Board under Standard State Agreement No. 4091400 for the period June, 1975, to March, 1976. A report on preliminary conclusions and recommendations was submitted to the California State Water Resources Control Board on February 27, 1976.

To control discharge of pollutants into navigable waters, EPA has a mandate under PL 92-500 to require the application of:

(a) "best practicable control technology currently available" (BPT or BPTCA) by July, 1977.

(b) "best available control technology economically achievable" (BAT or BATEA) by July, 1983.

(c) "elimination of discharge of pollutants" (EOD) by 1985.

The ultimate goal of EOD has been recently interpreted by the Staff of the National Commission on Water Quality as "the elimination of the discharge of pollutants shall apply to removal of those constituents which are added during use of the water. The resultant discharge must be of equal or lower concentration than that of the original supply." Moreover, EOD applies only to point-source discharge of pollutants, and not to nonpoint sources.

It should be pointed out that PL 92-500 does not explicitly identify the control technology desired, but only the goals to be achieved. However, in the implementation of this Act, uniform waste discharge requirements are being promulgated for municipal sewage effluents and most industrial wastewater discharges. For example, secondary treatment of municipal sewage effluents meets the 1977 BPT goal. Similar waste discharge requirement/control technology has not been spelled out for irrigation return flows. Yet, what is now being enforced is the National Pollutant Discharge Elimination System (NPDES) permit program, which does apply to surface irrigation return flows discharged from an identifiable source. The NPDES permit system, administered by the State Water Resources Control Board and its Regional Boards in California, initially involves a self-monitoring program in which permittees are required, among others, to report the flow, electrical conductivity, and suspended solids of supply and discharge waters.

Subsequent to the initiation of this project, EPA has recently started to develop a General Permit Program under NPDES that will also apply to agricultural point sources ("irrigation return flow conveyances"). If this proposed regulation is finalized, a General Permit Program Area (GPPA) will be issued. Among the goals of this modification in the permit system are simplification in administrative procedures and coordination with the ongoing Section 208 planning efforts.

Irrigation tailwater, in some quarters, is considered to be the easiest component to control of the point-source surface irrigation return flow. If

CHAPTER II. ACKNOWLEDGMENTS

We hereby acknowledge the generous contributions and support given to this investigation by field study site cooperators and interested collaborators. We have received expert advice and suggestions regarding the selection of possible field study sites and monitoring stations. We have also received ready access to records, and assistance in the collection of water samples and maintenance of monitoring stations as well as in the design, fabrication, and installation of certain water-flow measuring stations.

We are indebted to the following cooperators:

Mendota-Crows Landing Return Flow Group (C. W. Bates, T. McCullough)
Central California Irrigation District (W. Raznoff, R. Pfitzer, S. Cook)
Panoche Water District (R. Ram)
Broadview Water District (S. Durrenberger)
Los Banos Wildlife Area (J. Cawthon)
Firebaugh Canal Company (B. Camp)
Enrico Brothers Farm
R & N Farms
Sacramento Valley Water Quality Committee (D. E. Kienlen)
Glenn-Colusa Irrigation District (R. Clark, D. Haapala)
Rice Growers (R. Roberts, R. Keeley, M. Landberg, M. Garcia)

We are also indebted to numerous collaborators, to mention a few:

Central Valley Regional Water Quality Control Board (R. E. Merrill, W. Tyler, R. Van De Pol)
Soil Conservation Service (R. W. Robb, D. Briggs)
San Joaquin Valley Interagency Drainage Program (W. R. Johnston, L. Beck)
Department of Water Resources (R. F. Clawson, V. B. McIntyre, J. L. Welsh)
U.S. Bureau of Reclamation (M. H. Kenner, D. A. DeBruyn)

CHAPTER III. SCOPE OF PROJECT AND SUMMARY

The first-year annual progress report (Water Science and Engineering Paper 4011, April, 1976, 200 p.) covered the 1975 irrigation season (April through October) while this second-year annual progress report covers the period since November, 1975, to March, 1977, i.e., the 1976 irrigation season as well as the nonirrigation seasons (November through March) of 1975-76 and 1976-77.

This second-annual report includes Chapter IV which is a collection of publications and reports that have arisen from this project. Chapter IV serves as the interim summary and conclusions of our findings to date. A final project report is due September, 1977.

Not covered in Chapter IV are some activities that are still in the developmental stages. These include further attempts to obtain measured or estimated water-flow data, a more complete assessment of return flows during the nonirrigation seasons and impact, if any, of the drought conditions, a method to estimate the resource demand by the public for the Los Banos Wildlife Area, and additional economic studies on water management, in particular alternative return flow policy and management.

For these yet-to-be-completed activities, the following progress is reported and wherever possible preliminary observations and/or conclusions are made:

(1) It appears that only a few of the missing water-flow data will become available before the preparation of the final project report. The measurement or estimation of irrigation return flow is easier said than done.

(2) Northern and Central California have faced two successive years of severe drought. The 1976 seasonal (October, 1975-April, 1976) precipitation and runoff were comparable to the 1924 and 1934 hydrologic years which were

the driest years on record to the present while 1977 is now considered as the driest year of record with reservoir storage approaching record lows and runoff about 5-20% of normal. This project was initiated in March, 1975, which probably was the beginning of the present drought conditions.

Since the San Joaquin Valley field study area utilizes water imported from the Sacramento River Basin it appeared to have been unaffected in the 1975 and 1976 irrigation seasons (April-October) based upon our observations and field data. However, water deliveries in January-February, 1976, were much larger than usual and return flows appeared to be smaller in the fall of 1976 and winter of 1977. Data obtained from the 1976-77 nonirrigation season (November-March) indicate a decrease in return flow and increases in salinity and boron contents with concurrent decreases in suspended matter. It appears that flood water was held in place by operators of winter waterfowl habitats and winter irrigators prevented tailwater losses and/or captured and reused more return flows. For the 1977 irrigation season, which is beyond this project's field study period (ended in March, 1977) project water deliveries to this area have been cut back 75%. It is expected that cropping patterns, acreages, and cultural practices will be drastically modified, and the quantity and quality of irrigation return flow in the 1977 irrigation season will significantly affect downstream users and/or uses.

As for the Sacramento Valley field study area, differences were noted between the 1975 and 1976 irrigation seasons. Water diversion by Glenn-Colusa Irrigation District (GCID) in 1976 was the highest (866,000 ac/ft) in the district's history and the percent of net surface outflow was the lowest (21%) since a water measurement program was initiated in 1962. Irrigated acreage increased from 132,400 in 1975 to 140,200 acres in 1976, but rice acreage decreased by 10,000 acres with an increase in other crops such as milo and corn. The small grains such as wheat and barley were irrigated 3 to 4 times due to the lack of spring rainfall in 1976. It should be mentioned that GCID has riparian water rights to the Sacramento River and purchases project water only in the middle of summer. GCID for the 1977 irrigation season intends to discharge only about 5% of their diverted water into the Colusa Basin Drain and cut back rice acreage by about 40%.

(3) Wildlife management areas in the Central Valley of California receive large amounts of irrigation return flows to maintain fish and waterfowl habitats. The Los Banos Wildlife Area receives about 10,000 to 15,000 ac-ft of return flows per year. To estimate the value of irrigation return flows used in the Los Banos Wildlife Area, the State of California surveyed about 400 hunters during the 1976-77 hunting season. Information on socio-economic factors, hunting conditions, and possible hunting regulations has been tabulated from the surveys. The demand for waterfowl hunting in the Los Banos Wildlife Area and the derived value of irrigation water will be estimated from the socio-economic data.

(4) The economic analysis of irrigation return flow recycle systems is based on actual on-farm irrigation systems that have been operating in the San Joaquin Valley. Representative field level and farm level systems are modeled after these operations. The field level analysis compared alternative irrigation systems on the basis of irrigation cost per acre (for a 170-ac tomato field). It was found that a side-roll sprinkler system was the least expensive, having an irrigation cost of $127.79/ac. A furrow irrigated field using both gated pipe and a recycling system cost $150.25/ac. A hand-move sprinkler system cost $152.21/ac, and the conventional siphon and furrow system with no recycling of return flows cost $177.21/ac. A linear programming model was used to analyze a subsurface tile drain and recycle system under a variety of conditions of water quality, water

availability, and crops grown. Results indicated that a representative farm will recycle considerable quantities of drainage water, depending on the amount available and the price of other sources of irrigation water. The quantity of water reused ranged from 1790 ac-ft to 4349 ac-ft, representing, respectively, from 37% to 76% of total water applied.

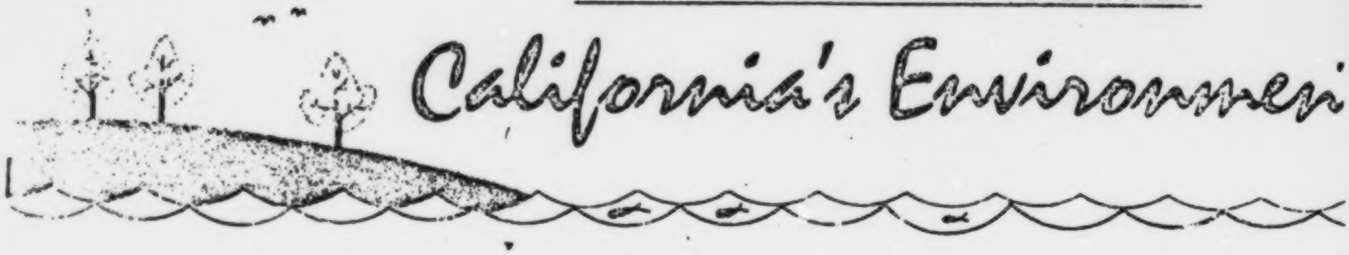
CHAPTER IV. PUBLICATIONS AND REPORTS

Several articles have been written on this project and they are reproduced as follows:

1. "Quality control of an often-overlooked water resource." R. Coppock and V. P. Osterli, *California's Environment*, Cooperative Extension Service, Univ. of Calif. No. 36, March-April, 1977. 4 pp.
2. "Farmers face real dilemma when throttling irrigation run-off." *The Sacramento Bee*, May 26, 1977, issue, page C2.
3. "PL 92-500: A tough act to follow." *Farm Index*, U.S. Dept. of Agriculture, June, 1977. p. 13.
4. "Surface irrigation return flows vary." K. K. Tanji, M. M. Iqbal, A. F. Quek, R. M. Van De Pol, L. P. Wagenet, R. Fujii, R. J. Schnagl, and D. A. Prewitt, *California Agriculture*, *Special Issue: Water*, Vol. 31(5):30-31.
5. "Evaluation of surface irrigation return flows in the Central Valley of California." K. K. Tanji, J. W. Biggar, R. J. Miller, W. O. Pruitt, and G. L. Horner, *Proceedings, National Conference on Irrigation Return Flow Quality Management*, May 16-19, 1977, Fort Collins, Colorado. J. P. Law, Jr., and G. V. Skogerboe, editors. pp. 167-173.
6. "An economic analysis of irrigation return flow recycle systems in the Central Valley of California." W. Kinney, G. L. Horner, and K. K. Tanji, *Proceedings, National Conference on Irrigation Return Flow Quality Management*, May 16-19, 1977, Fort Collins, Colorado. J. P. Law, Jr., and G. V. Skogerboe, editors. pp. 175-182.
7. "A conceptual hydrosalinity model for predicting salt load in irrigation return flows." K. K. Tanji, *Proceedings, International Conference on Managing Saline Water for Irrigation: Planning for the Future*, August 16-20, 1976, Lubbock, Texas. H. E. Dregne, editor. pp. 49-70.

8. "Estimation of crop water use in the Panoche Water District."
W. O. Pruitt, Unpublished Rept., Dept. of Land, Air and Water Resources, Univ. of Calif., Davis, July 5, 1976. 6 pp.

COOPERATIVE EXTENSION UNIVERSITY OF CALIFORNIA



California's Environmen

No. 36, March-April, 1977

QUALITY CONTROL OF AN OFTEN-OVERLOOKED WATER RESOURCE

One of California's important but less glamorous water resources is known as "tailwater."

Tailwater, of course, is surface flow that runs off the low end of a field being irrigated. Thus, it is one kind of agricultural drainage. But for at least two good reasons, tailwater should be thought of as different than farmland drainage that percolates down through the soil:

1. Physically, tailwater is separate from subsurface drainage water, although it often is collected in the same drainage canal.

2. Also, it is often much different in quality. In contrast to subsurface drainage, tailwater picks up virtually no salts from the soil--although it may carry off sediments and associated constituents such as pesticide residues.

Tailwater is one target of state and federal water quality control programs involving agriculture. As such, it is dealt with by a UC team of water researchers and economists in a report to the two chief control agencies--the Environmental Protection Agency and the State Water Resources Control Board.

The research team, headed by Water Scientist Kenneth Tanji*, is completing a two-year investigation of the possibilities for monitoring and controlling quality of return flows from agriculture. Although their report covers many aspects of agricultural return flow, this newsletter will concentrate on its discussion of tailwater.

Lower-end runoff: why and where

Irrigation systems where water flows along the surface of the ground (furrows in a field of corn; borders or "checks" in an irrigated pasture; basins in an orchard) usually produce tailwater. This is because the water must be kept flowing even after it reaches the lower end of the field so that there is ample time to soak down through the root zone.

Sometimes, it's necessary to send water across the field in a hurry--in one-fourth or one-third of the total time

---

*Members, all of UC, Davis: Tanji, J. W. Biggar, R. J. Miller, and W. O. Pruitt, Department of Land, Air and Water Resources; G. L. Horner, USDA-Economic Research Service.

The University of California's Agricultural Extension Programs are available to all, without regard to race, color, or national origin.

needed for it to filter down. Otherwise, water would move too slowly at the upper end and much would be wasted through deep percolation below the roots. But this, of course, allows even more time for tailwater to run off.

There are other circumstances when sizable flows of tailwater can't reasonably be avoided. For example, with surface irrigation methods it's almost impossible to apply just the right, uniformly distributed amount of water needed to germinate newly-planted seeds--without wetting large volumes of soil or without considerable runoff. So in seed germination, irrigation efficiencies as low as 15% to 25% are common--which often means a lot of tailwater.

(Irrigation efficiency is the percentage of applied water that's actually stored in the soil for crop use. Efficiency of 75% to 85% is considered very good; it takes special care in water management to do much better than 50% or 60%.)

Background:

Will the newer irrigation technologies --sprinklers and drip systems--eliminate the output of tailwater from California farms? That's an interesting question. In any case, it's unrealistic to simply expect all farmers to shift to sprinklers or drip under the existing economic rules of the game.

Well-designed sprinkler systems can apply water more efficiently than furrows, borders or basins. Of about 9.1 million irrigated acres in California today, about 20% are being sprinkled. And as irrigation water becomes more scarce and/or expensive, the amount of farmland under sprinklers will increase. But there's almost certainly an upper limit, for economic reasons if no other--some crop/land combinations just can't justify the cost of sprinklers.

Well-operated drip systems may use water even more efficiently than sprinklers. But they are even more expensive, hence appear to be economically suited mostly to orchards, vineyards and other high-value crops such as strawberries and certain vegetables --or where water costs are extremely high or there are other special problems.

Despite the potential increase in on-farm irrigation efficiency offered by sprinklers and drip systems, vast acreages of flat and fertile California farmland are still well suited to surface irrigation. If those acres keep on producing crops, the chances are they will keep on producing some tailwater, too. (As we shall see, this isn't necessarily waste.)

What's "efficient"?

Tailwater is commonly thought of as wasted water; and for the farmer who lets it flow off his land, it probably is. Also, tailwater may carry pollutants--sediment, and possible residues of pesticides or water-applied fertilizers. (But not much more salts than were in the incoming irrigation water.)

There is, however, more to the tailwater runoff question. In the words of the UC research team's report: "If tailwater is controlled and/or re-used, one could argue that irrigation application efficiency would be improved, water and energy would be conserved, and at the same time water quality problems would be substantially reduced. So tailwater management appears to be a logical and practical control technology. But the question is: Is it really?"

The answer, as you might guess, depends

on what happens to the runoff after it leaves the field being irrigated. Not all of it reaches the nearest stream or drainage canal; in areas where water is scarce and/or costly, it is often recycled by the farmer on his own land. This re-use, of course, is one form of control.

Or tailwater may be re-used by other farmers downstream. The UC report points out: "Even in areas where the supply of water is plentiful and inexpensive, it is not unusual to find from 15% to 30% of the diverted water running off but being re-used downstream. A recent California Department of Water Resources investigation on the west side of the Sacramento Valley indicated that although some individual farm irrigation efficiencies were low, the overall basin irrigation efficiency over a 10-year period was estimated to be 70%. This was primarily due to downstream re-use of irrigation tailwater."

It's also common practice to let tailwater percolate into ground water basins. And, of course, once it rejoins a stream it becomes part of the water supply again.

That last possibility--the effect of tailwater on streamflow--is an important consideration. It's estimated that return flows from a million acre area of irrigated land make up about one-fourth of the flow of the Sacramento River in July and August. And streamflow in some stretches of the San Joaquin River is virtually all farmland drainage during the irrigation season.

The dilemma is summed up by the UC report in these words: "It can be argued that control of surface irrigation return flows, elimination of tailwater in particular, may result in a greater water-use efficiency in irrigated agriculture...Such control, however, may lead to other problems such as diminished summer flow in streams, diminished supply for downstream water users, and inadequate out-flow to repel sea water intrusion into the Sacramento-San Joaquin Delta."

Rights to water quality?

Reducing the volume of tailwater not only may lower streamflow; it also may lower quality of water in the stream. This happens if the tailwater contains less salts (a not unusual circumstance) and so would improve the stream by diluting it.

If tailwater control programs actually result in degradation of streams, an interesting question would be raised: Do those who re-use water downstream have legal rights to quality of their supply? The upstream user, the report points out, has rights "only to the 'reasonable beneficial use' of a quantity of water, and any excess over this amount must be left for junior appropriators. It is not clear whether the rights to this excess water include any right to a certain level of quantity.

In any case, the question could end up in court.

Control procedures

The fact that tradeoffs must be taken into account doesn't mean that some form of tailwater control may not be appropriate. The UC water scientists list a number of possible alternatives, starting with the easiest and least expensive:

--Capture and re-use irrigation return flows within the basin or water district.

--Improve on-farm irrigation efficiency to attainable levels.

--Discharge only the tailwater that is

required by certain farming practices, such as wetting seedbeds to germinate seeds and lowering water levels in rice fields during strong winds.

--Build settling ponds to let sediments and certain other pollutants settle out before releasing tailwater.

--Build on-farm systems to recover and re-use tailwater.

--Allow limited tailwater discharges when streams are low in order to maintain or augment the flow. This would require holding reservoirs.

--Allow limited tailwater discharges when streams are high enough to safely dilute the pollutants. This, too, would require holding reservoirs.

--Finally, the most extreme measure: Prohibit the discharge of tailwater.

Any of these proposals may be necessary under specific circumstances; but none of them make sense under all circumstances. Discharging tailwater into surface streams may be either beneficial, detrimental, or both--depending on the levels of water quality and the amounts of flow. And what works in one location may not work so well in another.

For all problems of farmland drainage--surface and subsurface--the answers don't seem to be easy. The UC report concludes: "Irrigated agriculture is an unique institutional structure... Irrigated agriculture operates in an 'open system'...utilizing available natural resources such as sunlight, soil, water, etc., all of which are highly variable. Many of the natural conditions and processes under which irrigated agriculture operates are unmanageable/uncontrollable by man or, at best, difficult to manage...Thus, this industry will require pollution abatement controls and policies different from those of most other in industries..."

FROM THE EDITORS:

Your comments are invited. Our address is Cooperative Extension, University of California, Davis, CA 95616.

Ray Coppock
Ray Coppock
Communications Specialist

Victor P. Osterli
Victor P. Osterli
Assistant Director

FARMERS FACE REAL DILEMMA WHEN THROTTLING IRRIGATION RUN-OFF

The Sacramento Bee, May 26, 1977, page C2

Farmers who reduce their irrigation run-off to save water during the drought may be adding to the plight of other growers down stream, a University of California task force warns.

"It may be argued that control of surface irrigation return flows, elimination of tailwater in particular, may result in a greater water-use efficiency in irrigated agriculture," reports the UC team.

Such control, however, may lead to other problems. Summer flow in streams, diminished supply for down stream users, and intrusion of sea water into the Sacramento-San Joaquin Delta could result.

The report, presented by UC water researchers and economists to the Environmental Protection Agency and California Water Resources Control Board, is the result of a two-year investigation of the possibilities of monitoring and controlling quality of return flows from agriculture.

One area probed by the team, led by water scientist Kenneth Tanji, deals with tailwater, the surface flow that runs off the low end of the field being irrigated.

Tailwater should be considered different from farm land drainage that percolates down through the soil, according to UC specialists. Not only is it separate from subsurface drainage physically, it also varies in quality. Tailwater picks up virtually no salts from soil, although it may carry off sediments and associated constituents such as pesticide residue.

Tailwater is often considered wasted water, but the report states if tailwater is controlled or re-used "one could argue that irrigation application efficiency would be improved, water and energy conserved, and ... water quality problems would be substantially reduced."

But tailwater management may not be a logical and practical control technology, the researchers add. It depends on what happens to the run-off after it leaves the field being irrigated.

"Not all of it reaches the nearest stream or drainage canal; in areas where water is scarce or costly, it is often recycled by the farmer on his own land. This re-use constitutes one form of control."

Tailwater may also be re-used by downstream farmers. The UC report points out: "Even in areas where the supply of water is plentiful and inexpensive, it is not unusual to find from 15 per cent to 30 per cent of the diverted water running off but being re-used downstream.

"A recent California Department of Water Resources investigation on the west side of the Sacramento Valley indicated that although some individual farm irrigation efficiencies were low, the overall basin irrigation efficiency over a 10-year period was estimated to be 70 per cent. This is primarily due to downstream re-use of irrigation tailwater."

It is also common to let tailwater percolate into the ground water basins, eventually rejoining a stream to become part of the water supply again.

Estimates indicate that return flows from a million acres of irrigated land make up about one-fourth of the flow of the Sacramento River in July and August. Stream flow in some stretches of the San Joaquin River is virtually all farm land drainage during the irrigation season. For these reasons, the report cautions against extensive changes which would limit run-off.

Reducing the volume of tailwater not only may lower stream flow, but reduce the quality of the water in the stream as well. This happens if the tailwater contains less salts (not an unusual circumstance) and would improve the stream by diluting it.

The limiting of tailwater resulting in stream degradation raises the legal question of whether those who re-use water downstream have legal rights to quality of their supply.

But where tailwater control is practical, the UC researchers suggest capturing and reusing the return flow within the basin or water district where it is originally used.

They recommend building on-farm systems to recover and re-use tailwater, allowing sediments and pollutants to settle out before releasing tailwater.

One method of limiting excessive run-off is by applying only the amount of water required by the plants. Well-designed sprinkler systems can apply water more efficiently than furrows, borders or basins, for example.

Of about 9.1 million acres in California today, 20 per cent are being sprinkled, with prospects improving for the system as water becomes more scarce and expensive.

But switching to sprinklers, or drip irrigation, is expensive. Some crop-land combinations cannot justify the cost of changing to more efficient irrigation programs, and vast acres of flat California farmland are well suited to surface irrigation.

If those acres continue to produce crops, chances are they will keep producing tailwater. And if drought causes these growers to curtail or prohibit discharge of this water, a backwash of complaints from downstream users could flood the courts with suits.

PL 92-500: A Tough Act to Follow

PL 92-500 is not just another number to some farmers.

As the legal code for the 1972 Federal Water Pollution Control Act, it has special significance to those who irrigate their lands.

The law's goal is to eliminate the discharge of pollutants into our Nation's waters by 1985. An interim goal is to achieve water quality that is "fishable and swimmable" by 1983. The goal, researchers are finding, may be tough for irrigators to achieve, though.

Under the National Pollutant Discharge Elimination System (NPDES), a permit is required from either the Environmental Protection Agency (EPA) or the designated State agency to discharge pollutants into waters—these pollutants include salts, nutrients, pesticide residues, and sediments as well as industrial wastes. Farmers using irrigation must apply for an NPDES permit and self-monitor their surface irrigation drainage in terms of both amount and content—salinity, suspended matter, etc.

Irrigation's importance. Since over 40 million acres of our harvested cropland—or nearly 12 percent—is irrigated, any law pertaining to irrigation waters can affect a sizable portion of the farm sector.

The 17 western States account for around 90 percent of the irrigated lands, California leading with 9 million irrigated acres. Texas is next in line with 8 million irrigated acres.

What are the impacts of PL 92-500 on irrigated agriculture, and how can agriculture comply with the law's statutes? The Environmental Protection Agency and the Economic Research Service have been supporting a 2-year study on these questions at the University of California at Davis.

Timetable problems. Basically, the study has concluded that irrigated agriculture cannot meet the law's timetables due to various reasons:

- Unlike industry, irrigated agriculture doesn't have "plumbing and valves" with which to easily shut off or redirect water flow. In addition, irrigation is subject to the variable resources of sunlight, soil, and water.
- As far as agriculture is concerned, there may be conflicts between State regulations and the Federal law. For example, in California, the State's Porter-Cologne Water Quality Control Act applies not only to surface waters (as does PL 92-500), but ground waters as well.
- Irrigated agriculture gets back not only water and effluents that it originates, but also other runoff. Therefore, there is a potential danger that controlling irrigation water pollution on the surface may actually transfer the problems underground.
- Control of surface irrigation return flows may result in smaller emissions of pollutants, but they may be more concentrated. Also, other problems could develop, such as smaller summer flows in streams, a diminished supply for downstream water users, and in places near the coast, an inadequate flow to keep back sea water.
- Current State water laws are unclear as to what rights certain users have to the quality of the water they receive. Under the Doctrine of Prior Appropriation, the first user has seniority over all subsequent users on the watercourse, but his right extends only to "beneficial use"—a term open to question.
- Although the increased costs of controlling irrigation-related pollution would eventually be passed on to the consumer, the short-term effects on the farmers—particularly the smaller ones—could be substantial. In fact, in areas of the country where irrigation return flows are of poor quality, some farmers might be forced to abandon irrigated agriculture in the face of steep pollution-control costs.

Controls. Recognizing that pollution problems do exist in agriculture as well as in other sectors of the economy, the EPA-ERS study has some recommendations for controls.

In general, the study recommends that any such controls should be flexible, taking local conditions into consideration. Also, it stresses that long-term effects of controls should influence any policy decisions.

More specifically, the study proposes that any control measures deal with problems peculiar to irrigated agriculture, such as point/nonpoint pollutant sources, surface/subsurface return flows, and controllable/noncontrollable runoff. In addition, the study suggests a restructuring of the NPDES permit system to spread the costs of monitoring as well as cut down on the number of permits.

[Based on a report to the California State Water Resources Control Board, "Irrigation Tailwater Management, Conclusions and Recommendations With Regard to PL 92-500 and the NPDES Permit Program," by K. K. Tanji, J. W. Biggar, R. J. Miller, W. O. Pruitt, W. C. Kinney, and R. J. Schnagl, all at the University of California at Davis, and G. L. Horner, Natural Resource Economics Division.]

Surface irrigation return flows vary

Kenneth K. Tanji
Muhammad M. Iqbal
Ann F. Quek
Ronald M. Van De Pol
Linda P. Wagenet
Roger Fujii
Rudy J. Schnagl
Dave A. Prewitt

Much attention is being focused on irrigation return flows as a result of recent legislation on water quality and pollution control and the concern for water and energy conservation. Statewide, surface irrigation return flows are nearly nonexistent where water normally is scarce or expensive. This report describes the variations in flow and quality characteristics of surface drainage waters from two irrigation districts in California's Central Valley, and the factors that contribute to such variations.

Irrigation return flows and quality characteristics

The major components of surface return flows include surface runoff (irrigation tail water, rainfall runoff, and operational spills from distribution systems) and collected subsurface drainage (effluents from tile drainage and drainage wells, and subsurface waters intercepted by natural and man-made open channels).

With some exceptions, the various components of surface return flows are collected in the same drain regardless of their origin (surface or subsurface, point source or nonpoint source). A part of these drain waters is reused, either by plan or incidentally, at the site of production or downstream. The remainder is discharged with no readily apparent beneficial uses.

Table 1 shows expected differences in quality characteristics for collected irrigation return flows. These are described relative to the supply water, because actual concentrations in both supply and discharge waters are highly variable from place to place.

District supply water vs. drain water

Figure 1 is a schematic diagram of supply and drain waters for the Glenn-Colusa Irrigation District (GCID) in the west side of the Sacramento Valley; figure 2 is for the Panoche Drainage District (PDD) in the west side of the San Joaquin Valley. The dominant crop in GCID is rice, which is usually contour flooded throughout the growing season; the major crops in PDD are tomato, cotton, and other row and field crops, which are normally furrow irrigated.

GCID captures and reuses about 44 percent of its drain waters within the district and discharges the rest into the Colusa Basin Drain (CBD), where it is reused downstream before final discharge back into the Sacramento River. PDD and the neighboring Central California Irrigation District capture and reuse about 20 percent of PDD's surface drainage (not counting reuse at farm levels) and discharge the remainder into the Grasslands Water District, where it is reused in irrigated pastures and waterfowl habitats. A small part eventually enters the middle reaches of the San Joaquin River.

Table 2 presents the flow-weighted average quality of supply and drain waters from CGID and PDD. The implications of these data are of considerable importance. In CGID, the 2-fold increase in concentration of total dissolved solids (TDS) relative to supply water can be attributed to the usual 2- to 4-fold increase by evapotranspiration by crop plants. In PDD, however, the increase is 9.6-fold and must be attributed to the pickup of salts from the chemical weathering (dissolution) of native soil salts and minerals (primarily gypsum). This is confirmed by soil and tile drain water analyses.

The increase in concentration of suspended solids (SS) in drain water relative to supply water is 1.5-fold in GCID, and again much larger (3.9-fold) in PDD. This may be attributed to two major factors: (1) the flooded rice fields of GCID tend to act as settling basins for suspended matter, and (2) because of their physical and chemical properties, surface soils in the PDD are more susceptible to erosion under surface irrigation methods.

However, on a mass basis, only slightly more sediments were discharged by PDD than were brought in by the supply water (15,487 vs. 13,135 tons). The impact of pollutants on possibilities of water use often is appraised in terms of concentrations only; mass emission of pollutants also should be considered.

Rice fields vs. tile-drained farm

Table 3 summarizes data obtained from four commercial rice fields in GCID. The supply (inflow) and the surface runoff (outflow) waters were continuously monitored over the whole growing season, and various quality parameters were measured at weekly to twice-monthly intervals. The average amount of water applied was 7.64 acre-feet per acre (ac-ft/ac), of which 1.91 ac-ft/ac were discharged as spill water. (An estimated 3.37 ac-ft/ac were used in evapotranspiration, and 2.36 ac-ft/ac were lost by seepage.)

Although the concentration of TDS in the spill water increased 1.7-fold, the unit mass emission rate (lb/ac) was only 44 percent of that brought in by the supply water, which is in line with the district-wide 61 percent mass emission of salts. Note that concentration of suspended solids was reduced by about one half, and the mass by nearly one-tenth.

As for nutrients, the nitrogen concentration in the drain water was about 1½ times greater, but only 38 percent of the nitrogen brought in by the water was discharged. It should be noted that about 90 percent of the total nitrogen was in the form of organic nitrogen, which implies only small losses of chemical nitrogen fertilizers in runoff waters.

Table 4 contains water quantity and quality data for a tile-drained farm cropped to cotton, tomato, and wheat in the PDD. The grower blended drain waters captured from the Panoche Drain with fresh water obtained from the Delta-Mendota Canal (DMC). Quality parameters are given for the waters and for the tile effluents collected in two tile sumps. The extremely high salinity level, high boron content, and low sediment concentration of the tile effluents are due more to the dissolved salts, gypsum, and boron native to the soil than they are to the supply water.

A computer model predicted the total dissolved salts of tile effluents in PDD would be 7,150 mg/liter, which agrees with the 6,700 to 8,900 mg/liter (flow-weighted average of 7,380 mg/liter) reported in table 4. The model predicted the concentration of total dissolved solids in the surface irrigation return flow would be 1,820 mg/liter (and that it would have been only 460 mg/liter if gypsum were not present in the PDD soils). The measured concentration was 2,050 mg/liter (table 2).

In summary, the ranges of variations in the quality and quantity of surface irrigation return flows are highly site-specific, and are affected by the parameters presented here and by many other factors. Quantity is influenced by: availability and cost of supply water; irrigation application methods and efficiencies; extent of reuse at the on-farm, district, and basin levels; special cultural practices; and constraints on reuse due to the presence of excess boron, sodium, and chloride. Quality is influenced by: the supply water; presence of salts, boron, and nitrogen native to the soils; leaching fraction and salt pickup/salt deposition phenomenon; use of agricultural chemicals and wastes, such as animal manures; erodibility of surface soils and open drain channel banks; and discharges into irrigation drains by other sectors of society.

Kenneth K. Tanji is Associate Water Scientist and Principal Investigator, Muhammad M. Iqbal is Junior Developmental Engineer, Ann F. Quek is Staff Research Associate III, Ronald M. Van De Pol was Postgraduate Research Water Scientist, Linda P. Wagenet was Research Assistant, Roger Fujii and Rudy J. Schnagl are Research Assistants, and Dave A. Prewitt is Staff Research Associate I, all of the Department of Land, Air, and Water Resources, University of California, Davis.

This project staff acknowledges the overall guidance and support given by Co-Investigators J. W. Biggar, R. J. Miller and W. O. Pruitt of the same department and G. L. Horner of USDA-Economic Research Service. We also acknowledge the assistance of J. W. Goldinger, D. W. Wolfe, and J. A. Sellick for laboratory and field work. This investigation was made possible through the cooperation and support of Robert Clark and Richard Haapala of Glenn-Colusa Irrigation District and Ray Ram of Panoche Drainage District. This work was partly supported by EPA Grant No. R803603.

TABLE 1. Collected Surface Irrigation Return Flow Components and Their Expected Quality Characteristics as Related to Applied Waters

Quality parameters	Operational spills	Irrig. tail water	Subsurface drainage
General quality	0	+	+ +
Salinity	0	0, +	+ +
Nitrogen	0	0, +, + +	+ +, +
Oxygen-demanding organics	0	+, 0	0, –, – –
Sediments	0, +, –	+ +	– –
Pesticide residues	0	+ +	0, –, +
Phosphorus	0	+ +	0, –, +

0 = not expected to be much different than supply water
+ – = some slight increase (pickup) or decrease (deposition) may occur
+ + = usually expected to be significantly higher due to concentrating effects, application of agricultural chemicals, erosional losses, pickup of natural geochemical sources, etc.
– – = usually expected to be significantly lower due to filtration, fixation, microbial degradation, etc.

TABLE 2. Quality of Supply and Surface Drain Waters in Glenn-Colusa Irrigation District (GCID) and Panoche Drainage District (PDD) for the 1975 Irrigation Season

Quality Parameter	Supply water		Drain water	
	GCID	PDD	GCID	PDD
Electrical conductivity (EC), micromhos/cm	190	163	391	1 070
Total dissolved solids (TDS), mg/liter	116	215	244	2 051
Turbidity, Jackson Turbidity Units (JTU)	15	14	27	126
Suspended solids (SS), mg/liter	24	90	36	148

TABLE 3. Summary of Selected Quality Parameters from Four Rice Fields in Glenn-Colusa Irrigation District During the 1975 Irrigation Season

Quantity and quality	Inflow	Outflow	Percent emission
Water, ac-ft/ac	7.64	1.91	25
TDS, mg/liter	106	184	-
TDS, lb/ac	2,204	962	44
SS, mg/liter	68	36	-
SS, lb/ac	1,414	187	13
Total nitrogen, mg N/liter	1.16	1.74	-
Total nitrogen, lb/ac	24	9.0	38

TABLE 4. Quality of Blended Supply Water and Tile Effluents from a 1,675-acre Tile-drained Farm in the Panoche Drainage District During the 1975 Irrigation Season

Quantity and quality	DMC water	Captured drain water	Mixed supply water	Tile effluents	
Quantity, ac-ft	2,344	1,837	4,181	72	163
EC, micromhos/cm	768	1,963	1,386	11,568	8,540
TDS, mg/liter	206	1,266	880	8,897	6,713
Turbidity, JTU	24	59	38	5	1
SS, mg/liter	54	139	58	24	7
Boron, mg/liter	0.2	2.4	1.3	23	9

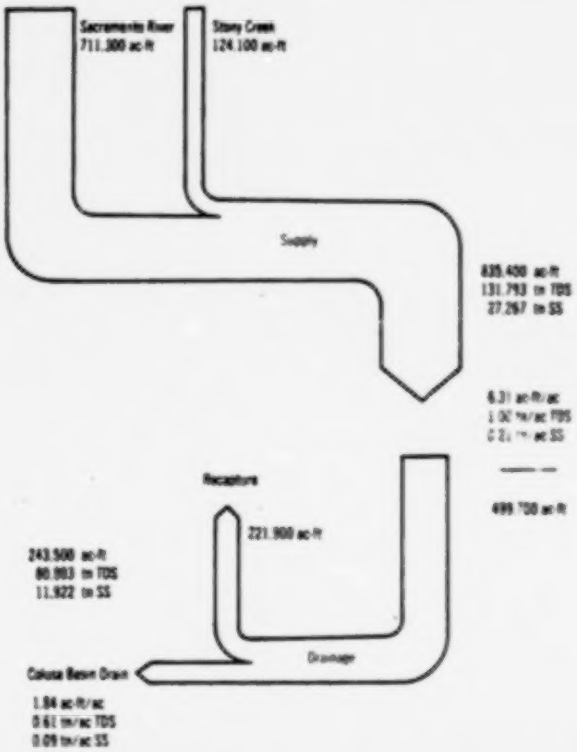

Sacramento River
711,300 ac-ft
Stony Creek
124,100 ac-ft
Supply
835,400 ac-ft
131,793 tn TDS
27,267 tn SS
6.31 ac-ft/ac
1.00 tn/ac TDS
0.21 tn/ac SS
499,700 ac-ft
Recapture
221,900 ac-ft
243,500 ac-ft
80,003 tn TDS
11,922 tn SS
Drainage
Colusa Basin Drain
1.84 ac-ft/ac
0.61 tn/ac TDS
0.09 tn/ac SS

Fig. 1. Irrigation and surface drainage in Glenn-Colusa Irrigation District during the 1975 irrigation (April-October) season. Water is reported in terms of acre-feet (ac-ft) and acre-feet per acre (ac-ft/ac); total dissolved solids (TDS) and suspended solids (SS) in tons (tn) and tons per acre (tn/ac).

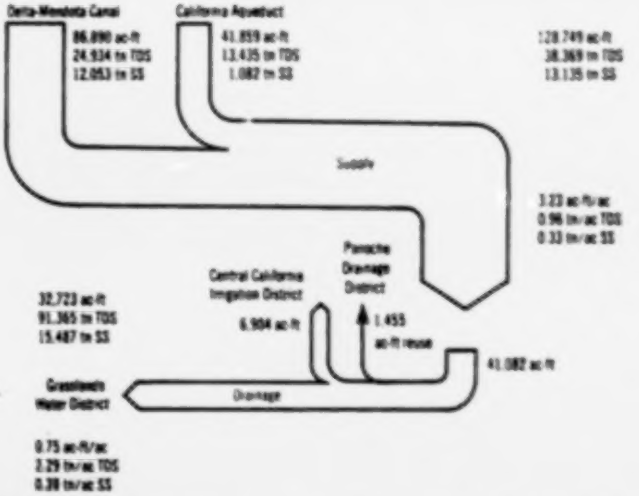

Delta-Mendota Canal
86,890 ac-ft
24,934 tn TDS
12,053 tn SS
California Aqueduct
41,859 ac-ft
13,435 tn TDS
1,082 tn SS
128,749 ac-ft
38,369 tn TDS
13,135 tn SS
Supply
3.23 ac-ft/ac
0.96 tn/ac TDS
0.33 tn/ac SS
Panoche Drainage District
Central California Irrigation District
32,723 ac-ft
91,365 tn TDS
15,487 tn SS
6,904 ac-ft
1,455 ac-ft reuse
41,082 ac-ft
Grasslands Water District
Drainage
0.75 ac-ft/ac
2.29 tn/ac TDS
0.38 tn/ac SS

Fig. 2. Irrigation and surface drainage in Panoche Drainage District during the 1975 irrigation (January-December) season.

PROCEEDINGS OF NATIONAL CONFERENCE

IRRIGATION RETURN FLOW QUALITY MANAGEMENT

Edited by:

James P. Law, Jr., Chief
Irrigated Agriculture Section
Robert S. Kerr Environmental Research Lab.
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

and

Gaylord V. Skogerboe, Professor
Dept. of Agricultural and Chemical Engrg.
Colorado State University
Fort Collins, Colorado 80523

Sponsored by:

U.S. Environmental Protection Agency

and

Colorado State University

May 16-19, 1977
Colorado State University
Fort Collins, Colorado

Evaluation of Surface Irrigation Return Flows in the Central Valley of California

KENNETH K. TANJI, JAMES W. BIGGAR, ROBERT J. MILLER
WILLIAM O. PRUITT and GERALD L. HORNER
Department of Land, Air and Water Resources, University of California,
Davis, California
Natural Resource Economics Division, Economic Research Service,
U.S. Department of Agriculture, Davis, California

ABSTRACT

The variability in the quantity and quality of surface return flows from two typical irrigation districts is reported for the 1975 and 1976 irrigation seasons. Factors contributing to such variations are noted. Emphasis is placed upon the concentration and mass emission of TDS and SS. The implications of these findings are discussed relative to PL 92-500 and best management practices.

INTRODUCTION

The Great Central Valley (Sacramento and San Joaquin Valleys) of California contains about 6.86 million acres of irrigated croplands out of the total 9.1 million acres statewide (3). Field crops (irrigated pasture, alfalfa, cotton, small grains, rice, sugar beets, corn) make up about 70% of this acreage, tree and vine crops (grapes, almond, walnut, peaches, prunes, citrus) about 22%, and vegetable crops (tomato, beans, potato) about 8% (3). On a statewide basis, about 41% of the 9.1 million acres are irrigated by the border method, 34% by furrow, 8% by sprinkler, and the remainder by drip and subirrigation methods (3). The depths of applied water in the Central Valley range from 3.2 to 4.9 ft for field crops, 2.8 to 3.7 ft for tree and vine crops, and 2.4 to 2.7 ft for vegetable crops (3). It has been estimated (2) that about 30% of the applied water in the Sacramento River and San Joaquin River Basins is discharged as surface return flows.

Much attention is now being focused upon irrigation return flows due to recent legislation on water quality and pollution control, and the concerns for water and energy conservation. Figure 1 identifies the major water-flow pathways in the crop root zone portion of irrigated lands and the components of surface return flows; namely, surface runoff (irrigation tailwater, precipitation runoff, operational spills from distribution systems) and collected subsurface drainage (effluents from tile drainage and drainage wells, and subsurface waters intercepted by natural and man-made open channels). With some exceptions, these components of surface irrigation ruturn flows are collected in the same drain regardless of their origin: surface or subsurface, point or nonpoint source. Some of these drain waters are reused, either planned or incidental, at the site of production or downstream, while the remainder is discharged with no readily apparent beneficial uses. It should be noted that surface irrigation return flows in California are nearly nonexistent where water is scarce and/or expensive.

This report presents some data on the flow and quality characteristics of surface irrigation returns from two typical irrigation districts for the 1975 and 1976 irrigation seasons. Differences in the quantity and quality of return flows are noted, with particular regards to total dissolved solids (TDS) and suspended solids (SS), and attempts are made to relate these differences to site specific factors and conditions. In addition, the information and data are evaluated with regards to PL 92-500 and potential best management practices.

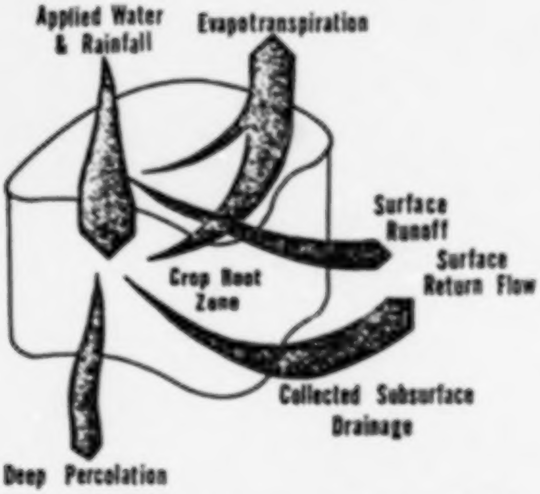

Applied Water & Rainfall
Evapotranspiration
Surface Runoff
Surface Return Flow
Crop Root Zone
Collected Subsurface Drainage
Deep Percolation

Figure 1. The major water-flow pathways in the crop root zone portion of irrigated lands. Surface return flow is comprised of surface runoffs and collected subsurface drainage.

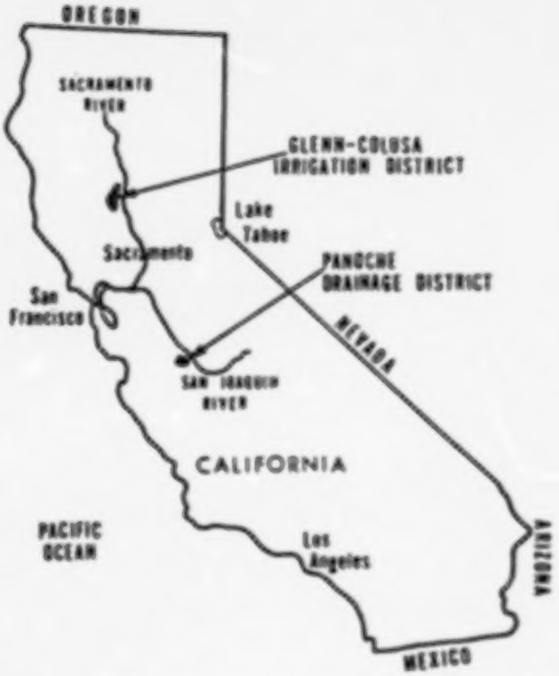

OREGON
SACRAMENTO RIVER
GLENN-COLUSA IRRIGATION DISTRICT
Lake Tahoe
Sacramento
PANOCHE DRAINAGE DISTRICT
San Francisco
NEVADA
SAN JOAQUIN RIVER
CALIFORNIA
PACIFIC OCEAN
Los Angeles
ARIZONA
MEXICO

Figure 2. Location map pointing out two study areas in the Great Central Valley of California.

DESCRIPTION OF STUDY AREAS

Figure 2 gives a location map of the two irrigation districts considered, Glenn-Colusa Irrigation District (GCID) in the Sacramento River Basin and Panoche Drainage District (PDD) in the San Joaquin River Basin. GCID, Figure 3, is a 163,700 acre district that obtains its supply waters by diversions from the Sacramento River and Stony Creek, and discharges its return flows via 11 lateral drains into the 70-mile Colusa Basin Drain (CBD), which has an outfall to the Sacramento River above Knights Landing as well as to the Yolo Bypass. PDD, Figure 4, is a 43,800 acre district that receives imported water from the Sacramento River Basin via the Delta-Mendota Canal and the California Aqueduct. Its return flows are discharged mainly into the

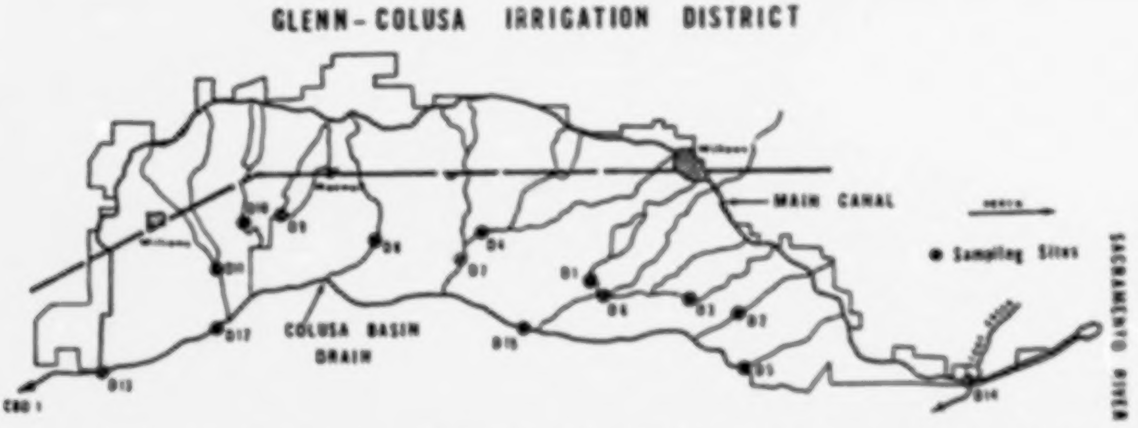

GLENN-COLUSA IRRIGATION DISTRICT
MAIN CANAL
NORTH
Sampling Sites
SACRAMENTO RIVER
COLUSA BASIN DRAIN
D10
D9
D8
D11
D17
D13
CBD 1
D4
D7
D1
D6
D3
D2
D15
D5
D14

Figure 3. Map of the 163,700 acre Glenn-Colusa Irrigation District in the Sacramento River Basin of California.

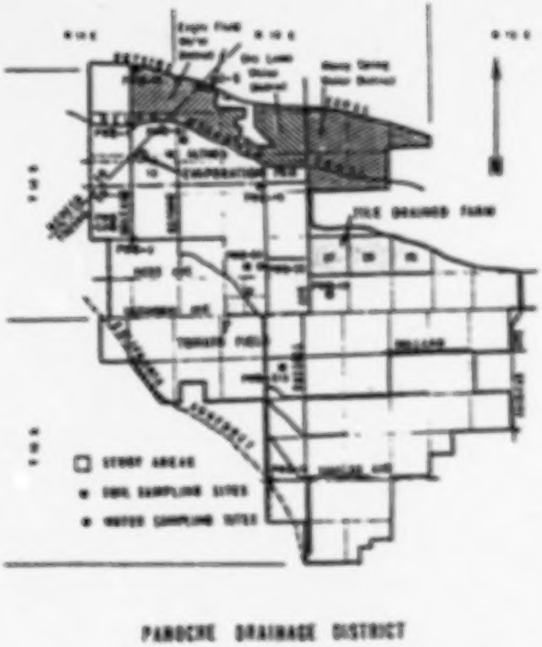


Figure 4. Map of the 43,800 acre Panoche Drainage District in the San Joaquin River Basin of California.

Grasslands Water District (GWD) for reuse by irrigated pastures and waterfowl habitats, and ultimately discharged into the middle reaches of the San Joaquin River. Other significant reuse of return flows discharged into the Sacramento and San Joaquin Rivers is also made by downstream users.

The major crop grown in GCID is rice (70% of irrigated acreage in 1975 and 58% in 1976) which is continuously flooded throughout the growing season. Irrigation usually begins in April and ends in October. The major crops grown in PDD are cotton, tomatoes, and melons which are furrow irrigated, and barley and wheat which may receive some pre-irrigation or irrigation depending upon winter rainfall. In PDD irrigation is practiced year-round, except in November and December when the usual maintenance and repairs take place.

WATER QUANTITY AND QUALITY

Table 1 gives detailed analyses of the supply and drain waters based upon the average of 3 to 4 grab samples taken over each irrigation season. The quality of the supply waters for GCID is excellent while the drain waters have not been degraded significantly. In contrast, for PDD the supply waters are similar to the quality of drain waters from GCID and its drainage waters are substantially degraded with regards to dissolved mineral salts, turbidity, nitrogen, and boron. Table 2 describes differences in quality characteristics for the several components of collected surface irrigation return flows relative to the supply water. The substantial degradation of drain waters from PDD may

TABLE 1

Quality of supply and drain waters in Glenn-Colusa Irrigation District (GCID) and Panoche Drainage District (PDD)

	GCID, 1975		*GCID, 1976*		*PDD, 1975*		*PDD, 1976*	
Quality parameters	*Supply*	*Drain*	*Supply*	*Drain*	*Supply*	*Drain*	*Supply*	*Drain*
EC, micromhos/cm	117	418	133	386	389	2,779	473	2,801
Solutes in meq/liter								
Na	0.22	1.92	0.32	1.86	1.75	15.3	2.09	16.7
Ca	0.50	1.22	0.45	1.20	1.22	8.58	1.16	8.58
Mg	0.40	1.39	0.46	1.48	0.97	3.90	1.05	4.75
HCO_3	0.99	3.00	1.18	3.26	1.57	3.22	1.71	3.03
Cl	0.07	0.48	0.10	0.54	1.41	11.6	2.01	12.1
SO_4	0.08	0.85	0.06	0.91	0.76	13.8	0.91	14.7
Turbidity, JTU	9	25	6	23	31	125	24	180
BOD_5,mg/liter	3.0	2.6	0.9	2.2	0.6	0.6	1.1	1.2
Nitrogen in mg N/liter								
Total N	~~0.94~~ 1.04	1.31	0.83	1.29	1.13	13.5	1.43	17.1
Org. N	0.87	1.03	0.71	1.00	0.46	0.70	0.75	1.14
NH_4	0.03	0.07	0.04	0.15	0.05	0.10	0.04	0.19
NO_3	0.14	0.19	0.10	0.17	0.62	12.6	0.64	13.4
Boron, mg/liter	—	—	—	—	0.12	4.3	0.11	4.4

TABLE 2

Collected surface irrigation return flow components and their quality characteristics as related to applied waters.

Quality parameters	*Operational spills*	*Irrigation tailwater*	*Subsurface drainage*
General quality	0	+	++
Salinity	0	0, +	++
Nitrogen	0	0, +, ++	++, +
Oxygen demanding organics	0	+, 0	0, -, --
Sediments	0. +, -	++	--
Pesticide residues	0	++	0, -, +
Phosphorus	0	++	0, -, +

0 = not expected to be much different than

+, - = some slight increase/pickup or decrease/ deposition may occur.
++ = usually expected to be significantly higher due to concentrating effects, application of agricultural chemicals, erosional losses, pickup of natural geochemical sources, etc.
-- = usually expected to be significantly lower due to filtration, fixation, microbial degradation etc.

be largely attributed to the collected subsurface drainage which is affected by the presence of native soil salts, boron and nitrogen, and the production of sediments from the highly erodible Panoche soils (6).

Figures 5 and 6 show monthly flows and concentrations of TDS and SS for supply and drain waters in GCID and PDD, respectively (6, 7). The 1975 irrigation season was in a "normal" hydrologic year while the 1976 irrigation season was in a "drought" hydrologic year. The flows of supply and discharge waters in GCID are dominated by flooded rice culture. Rice is planted in late April to early May and irrigated until late August to early September, which is reflected by the flows in Figure 5. The drain outflow is usually characterized by peak flows in the early and late irrigation periods. The former is due to lowering of water levels in rice fields to prevent erosion of levees by gusty winds that usually occur in May and the latter is due to the draining of rice fields prior to harvesting in mid-September and early October. The peak irrigation and drain outflow months in PDD usually occur between March and August for field and vegetable crops, but water is delivered year-round because of less precipitation in PDD than in GCID (7.73 and 10.65 inches in PDD during October through September for 1974/75 and 1975/76 hydrologic years vs. 19.56 and 6.58 inches in GCID, respectively) and to some extent double cropping.

Figures 7 and 8 contain schematic diagrams for supply and surface drain waters for both the 1975 and 1976 irrigation seasons in GCID and PDD, respectively. Included in these diagrams are seasonal quantities of supply water and their sources; gross quantities of

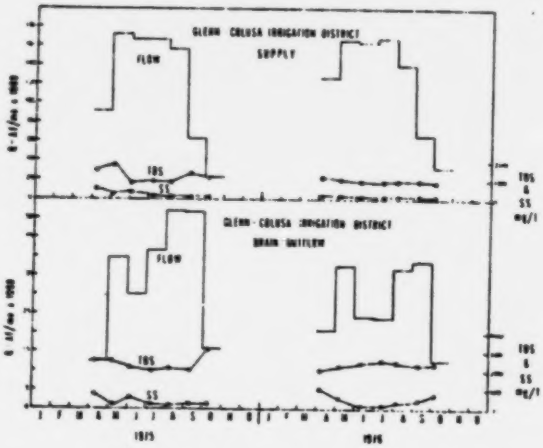


Figure 5. Monthly flows of supply and drain waters in Glenn-Colusa Irrigation District over two irrigation seasons and concentrations of total dissolved solids and suspended solids.

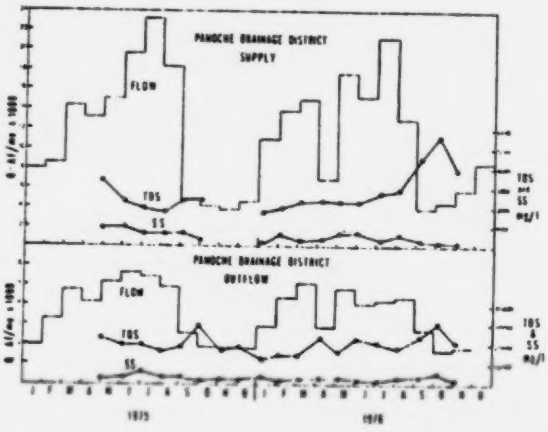


Figure 6. Monthly flows of supply and drain waters in Panoche Drainage District over two irrigation seasons and concentrations of total dissolved solids and suspended matter.

drainage, part of which are captured and reused within the district and remainder discharged; irrigated acreages; unit application and unit drainage rates (acre-feet/acre); and corresponding masses (concentration x water volume) of TDS and SS (tons); as well as unit mass application and unit mass emission rates (tons/acre). It is not possible herein to fully discuss these data, but an attempt will be made to point out the major findings.

In GCID, an increase of 7,800 acres of irrigated lands occurred between 1975 and 1976 with a corresponding increase in diverted water, but the unit application rate was slightly less (6.31 vs. 6.18 acre-feet/acre) due mainly to a reduction of 12,136 acres in rice. In contrast, there was a decrease of 2,870 acres of irrigated lands in PDD from 1975 to 1976 and a corresponding decrease in imported water, but the unit application rates were nearly the same. Of the 465,400 and 398,500 acre-feet of drain water produced in GCID in 1975 and 1976, respectively, about half of it was captured and reused within the district. The net discharge of surface irrigation return flow was 29 and 21% of diverted water in 1975 and 1976, respectively. For comparison, PDD recaptured only 3.5 and 10.4% of their drain waters from the 1975 and 1976 irrigation season, respectively. Central California Irrigation District (CCID) also used 16.8 and 19.3% of PDD's drain waters in 1975 and 1976, respectively. The remainder of the surface return flows were discharged into the Grasslands Water District (GWD). The unit drainage rate was 0.91 and 0.85 acre-feet/acre for these two irrigation seasons in PDD as compared to 1.84 and 1.31 acre-feet/acre in GCID. These differences may be largely attributed to irrigation application methods and crop culture.

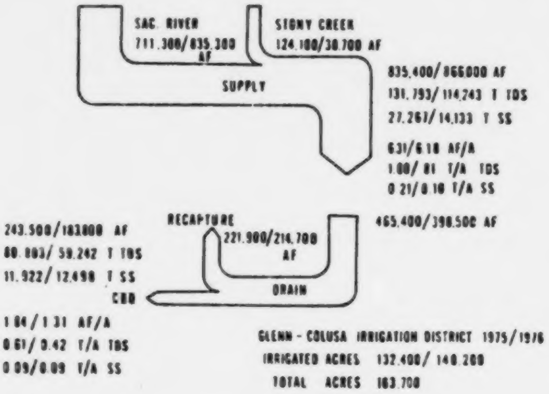

SAC. RIVER
711.300/835.300 AF
STONY CREEK
124.100/30.700 AF
SUPPLY
835.400/866000 AF
131.793/114.243 T TDS
27.267/14.133 T SS
6.31/6.18 AF/A
1.00/.81 T/A TDS
0.21/0.10 T/A SS
RECAPTURE
221.900/214.700 AF
465.400/398.500 AF
243.500/183800 AF
80.803/59.242 T TDS
11.922/12.498 T SS
CBD
DRAIN
1.84/1.31 AF/A
0.61/0.42 T/A TDS
0.09/0.09 T/A SS
GLENN - COLUSA IRRIGATION DISTRICT 1975/1976
IRRIGATED ACRES 132.400/140.200
TOTAL ACRES 163.700

Figure 7. A schematic diagram of seasonal surface inflow and surface outflow of water, salts, and sediments over two irrigation seasons in Glenn-Colusa Irrigation District.

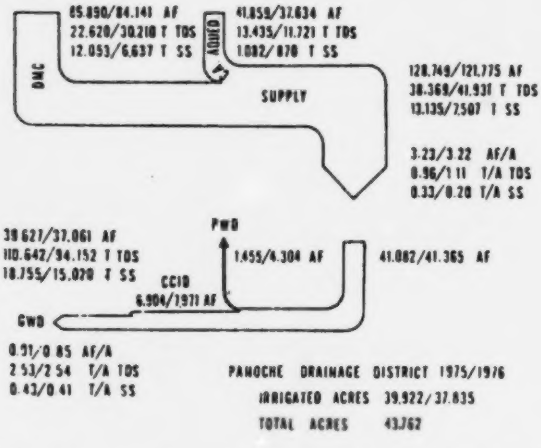

85.890/84.141 AF
22.620/30.210 T TDS
12.053/6.637 T SS
AQUED
41.859/37.634 AF
13.435/11.721 T TDS
1.082/870 T SS
DMC
SUPPLY
128.749/121.775 AF
38.369/41.931 T TDS
13.135/7.507 T SS
3.23/3.22 AF/A
0.96/1.11 T/A TDS
0.33/0.20 T/A SS
PWD
39.621/37.061 AF
110.642/94.152 T TDS
18.755/15.020 T SS
1.455/4.304 AF
41.082/41.365 AF
CCID
6.904/7.971 AF
GWD
0.91/0.85 AF/A
2.53/2.54 T/A TDS
0.43/0.41 T/A SS
PANOCHE DRAINAGE DISTRICT 1975/1976
IRRIGATED ACRES 39.922/37.835
TOTAL ACRES 43.762

Figure 8. A schematic diagram of seasonal surface inflow and surface outflow of water, salts, and sediments over two irrigation seasons in Panoche Drainage District.

The monthly flow-weighted average concentration of TDS (mainly dissolved mineral salts) in GCID's supply water was 116 and 97 mg/liter and drain water 244 and 237 mg/liter for the 1975 and 1976 seasons, respectively, about a 2.1- and 2.4-fold increase in concentration. In contrast, the TDS in PDD's supply water was 219 and 254 mg/liter and drain water 2,053 and 1,868 mg/liter for the 1975 and 1976 seasons, respectively, and a 9.4- and 7.4-fold increase. But, on a mass basis, Figure 7 for GCID indicates only 61 and 52% of the TDS in 1975 and 1976 irrigation water, respectively, were discharged into CBD while Figure 8 for PDD indicates 288 and 225% for the corresponding values. With regards to TDS, the increase in concentration of TDS in drain water relative to the supply water for GCID is in the usual range of 2- to 4-fold increase from the evapotranspiration concentrating effects by crop plants. The remainder of salts brought in by the irrigation water presumably is lost as deep percolation since accumulation of salts in soils is not observed. On the other hand, the 9.4- and 7.4-fold increase in the concentration of TDS in PDD's drain waters must be attributed to the pickup of salts through chemical weathering of native soil salts and minerals. Soil analyses (6) from PDD show that EC_e typically ranges from 1.6 millimhos/cm in soils containing large amounts of gypsum (greater than 10 T/AF). Results from a conceptual hydrosalinity model (4) indicate gypsum contributes about 25 meq/liter of salts (2,152 mg/liter TDS) to the soil solution. Furthermore, this computer model indicates if gypsum was not present, the TDS of surface irrigation return flow from PDD would be 458 mg/liter instead of the monitored 2,053 mg/liter in 1975. For comparison, the computer predicted 1,818 mg/liter in the presence of gypsum.

The monthly flow-weighted average concentration of SS (mainly sediments) in GCID's supply water was 24 and 12 mg/liter and drain water 36 and 50 mg/liter for the 1975 and 1976 irrigation seasons, respectively. But the mass of SS discharged into Colusa Basin Drain (CBD), Figure 7, was 44 and 88% of that brought into the district from the supply water. Likewise, SS in PDD's supply water was 75 and 45 mg/liter and drain water 348 and 298 mg/liter for the 1975 and 1976 irrigation seasons, respectively, a 4.6- and 6.6-fold increase in concentration. However, on a mass basis, Figure 8, the SS discharged into GWD and CBD was 1.4 and 2.0 times the amount brought into the district from their supply water. The difference in unit mass emission rate of SS from GCID as compared to PDD may be attributed to the fact that flooded rice fields in GCID more or less act as settling basins for SS while the soils in PDD are highly erodible (6).

DISCUSSION

The implications of the above evaluations on concentration and mass emission of TDS and SS are of considerable importance. While it is recognized that impact of pollutants on the beneficial uses of waters may be appraised in terms of concentration, the effectiveness of controlling discharge of pollutants should not only be considered in terms of concentration but also on a mass emission basis. If concentration is overly stressed, this tends to promote inefficient water management (5).

A survey (5, 6) of typical ranges of variations in the quality and quantity of surface irrigation return flows along with the data presented herein indicates the quantity and quality of surface irrigation may be highly variable and site specific. This particular conclusion should be considered for irrigation return flows (point or nonpoint, collected or uncollected) when contemplating future water quality and pollution controls. Some of the principal factors affecting how much irrigation return flows are generated include: availability and cost of supply water; irrigation application methods and efficiencies; extent of reuse of drain waters at the onfarm, district and basin levels; soil physical conditions; and special cultural practices such as the lowering of water in flood rice fields during strong winds to prevent erosion of levees to germination of seeds in furrow beds. Some of the principal factors affecting the quality of surface irrigation return flows are: quality of supply water; presence of native soil salts, boron and nitrogen; leaching fraction and salt pickup-salt deposition phenomena; use of agricultural chemicals such as fertilizers and soil amendments; insecticides and herbicides, animal manures and wastewaters; crop and other plant residues; erodibility of surface soils and open drain channel banks; sedimentation and resuspension of suspended matter as affected by current velocity and size fraction; and discharges into irrigation drainage canals by other sectors of society including other agricultural activities, municipal and industrial treatment plants, silviculture, rangelands and watersheds.

In our opinion irrigated agriculture is a unique institutional structure for which effluent guidelines and "end of the pipe" controls promulgated in PL 92-500 cannot be applied as reasonably as in most other industries. It is our contention that irrigated agriculture does not have the "plumbing and valves" found in industrial and sewage treatment plants. Irrigated agriculture operates in an "open system" in contrast to a "closed system" (as in most other industries). Many of the natural conditions and processes under which irrigated agriculture operates are unmanageable or uncontrollable by man, or, at best, difficult to control. Thus, if irrigated agriculture is to comply with the intent of PL 92-500, this industry will require pollution abatement controls and policies different from those of most other industries.

It is suggested that due considerations instead be given to "best management practices" rather than concentrating on waste discharge requirements. A recent publication (1) points out alternative control and management practices for surface irrigation return flows. Since irrigation tailwater is considered to be easiest to control of the components of surface irrigation return flows, tailwater management appears to be a logical best management practice. However, the effects of tailwater discharge into surface waters may be either beneficial, detrimental, or both, depending on the quality constituents of interest and water flow. Be that as it may, for application to Central Valley conditions, Figure 9 presents an array of alternative controls on tailwater production and potential pollution of surface receiving water bodies (5). Some of these tailwater management practices may be broadly applicable, while others are not because they require extensive structural modifications and/or costly water control. Due to the site variability of receiving waters and of tailwater production and quality, it is difficult to recommend any single universally applicable best management practice. A practice that is effective in one location may not be as effective in another.

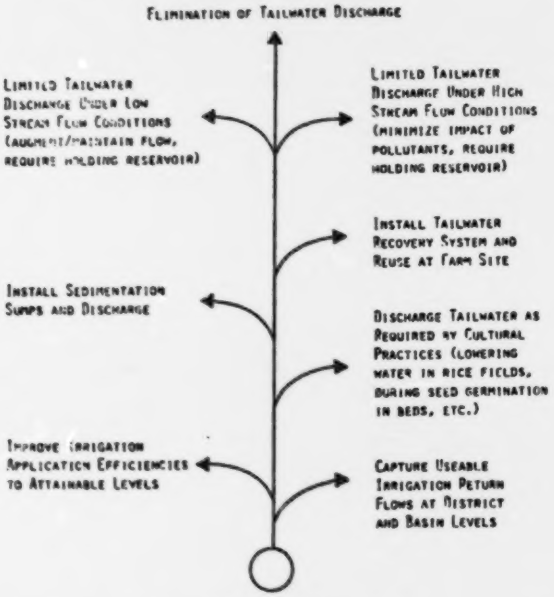

Elimination of Tailwater Discharge
Limited Tailwater Discharge Under Low Stream Flow Conditions (Augment/Maintain Flow, Require Holding Reservoir)
Limited Tailwater Discharge Under High Stream Flow Conditions (Minimize Impact of Pollutants, Require Holding Reservoir)
Install Tailwater Recovery System and Reuse at Farm Site
Install Sedimentation Sumps and Discharge
Discharge Tailwater as Required by Cultural Practices (Lowering Water in Rice Fields, During Seed Germination in Beds, etc.)
Improve Irrigation Application Efficiencies to Attainable Levels
Capture Useable Irrigation Return Flows at District and Basin Levels

Figure 9. An array of potential best management practices for the control of irrigation tailwater and potential pollution of surface receiving water bodies.

ACKNOWLEDGMENT

This investigation was supported mainly by EPA Grant Nos. R 803603-01-1 and R 803603-02-1. This particular phase of the investigation was made possible through the cooperation and support of Glenn-Colusa Irrigation District and Panoche Drainage District.

REFERENCES

1. Carter, D. L., and Bondurant, J. A. 1976. Control of sediments, nutrients, and adsorbed biocides in surface irrigation return flows. EPA-600/2-76-277, October, Environmental Protection Technology Series, US EPA, 53 p.

2. State Water Resources Control Board. 1975. Water Quality Control Plan Report, Sacramento River Basin (5A), Sacramento-San Joaquin Delta Basin (5B), and San Joaquin River Basin (5C). Vol. II.

3. Stewart, J. I. 1975. Irrigation in California. Report to the California State Water Resources Control Board, University of California, 64 p.

4. Tanji, K. K. 1977. A conceptual hydrosalinity model for predicting salt load in irrigation return flows. *In* Proc. Intern. Conf. on Managing Saline Water for Irrigation: Planning for the Future. 16-20 August 1976 (in press).

5. Tanji, K. K., Biggar, J. W., Horner, G. L., Miller, R. J., and Pruitt, W. O. 1976. Irrigation tailwater management. Conclusions and recommendations with regards to PL 92-500 and the NPDES Permit Program. Report to the California State Water Resources Control Board for Standard State Agreement No. 4091400, March, 58 p.

6. Tanji, K. K., Biggart, J. W., Horner, G. L., Miller, R. J., and Pruitt, W. O. 1976. Irrigation tailwater management. 1975-76 Annual Report to U.S. EPA on EPA Grant No. R 803603-01-1, University of California at Davis, Water Science and Engineering Paper 4011, April, 200 p.

7. Tanji, K. K., Biggar, J. W., Horner, G. L., Miller, R. J., and Pruitt, W. O. 1977. Irrigation tailwater management. 1976-77 Annual Report to U.S. EPA on EPA Grant No. R 803603-02-1. (under preparation.)

PROCEEDINGS OF NATIONAL CONFERENCE

IRRIGATION RETURN FLOW QUALITY MANAGEMENT

Edited by:

James P. Law, Jr., Chief
Irrigated Agriculture Section
Robert S. Kerr Environmental Research Lab.
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

and

Gaylord V. Skogerboe, Professor
Dept. of Agricultural and Chemical Engrg.
Colorado State University
Fort Collins, Colorado 80523

Sponsored by:

U.S. Environmental Protection Agency

and

Colorado State University

May 16-19, 1977
Colorado State University
Fort Collins, Colorado

An Economic Analysis of Irrigation Return Flow Recycle Systems in the Central Valley of California

WILLIAM KINNEY, GERALD L. HORNER, and KENNETH K. TANJI
Department of Agricultural Economics, University of California, Davis;
Economic Research Service, USDA;
and Department of Land, Air and Water Resources, University of California, Davis

ABSTRACT

Irrigation return flow recycle systems have been used in California for a number of years under a variety of crop rotations, soil characteristics and qualities of irrigation water. Recycle systems operating on the field, farm and district level were compared on the basis of cost in two areas of the San Joaquin Valley. The effects of three scales of recycle systems on the least-cost combination of irrigation water delivery systems and water management techniques were evaluated.

INTRODUCTION

In an annual progress report to the Environmental Protection Agency, it was concluded that the production of tailwater occurred in irrigated areas where water costs were low, water supplies plentiful, high water use did not affect yields and facilities for tailwater disposal existed (Tanji, 1976, p. 18). The report also recommended that the amount of tailwater could be reduced by either adopting more efficient water application methods or managing the present systems more carefully.

Public Law 92-500 has established water quality goals that could require a substantial reduction in the amount of disposed tailwater. Therefore, determining the cost of alternative methods of reducing tailwater is important in selecting a least cost policy to achieve the goals established in PL 92-500. This paper contains an evaluation of farm and field level irrigation methods and systems used in the San Joaquin Valley that eliminate or substantially reduce the amount of tailwater produced.

Irrigated agriculture uses about 85 percent of the developed water in California and about 75 percent of the state's irrigation water is used in the Central Valley. Field crops dominate the Central Valley agriculture and about 90 percent of them are irrigated by border and furrow methods.

A reliable estimate of the amount of tailwater produced in the Central Valley does not exist. In 1975, the Central Valley Regional Water Quality Control Board required many of the irrigated areas to have a permit for the disposal of irrigation return flows. The permit requires the monitoring and reporting of the flow, electrical conductivity and suspended solids of supply and discharge waters. These results will provide more insight into irrigation efficiencies in the Central Valley and facilitate a more comprehensive economic evaluation of tailwater disposal.

CONTROLLING TAILWATER IN A FIELD

Furrow irrigation typically produces runoff in a field of 20 to 40 percent of the water applied (Tanji, 1976, p. 16). Attempts to reduce the stream of water to control runoff usually result in poor water distribution and reduced crop yields. The installation of a tailwater reuse system can eliminate runoff by collecting the tailwater in a sump at the lower end of the field and pumping it back to the head of the field for reuse. The reuse system allows maximum stream flow, water penetration and high irrigation efficiency.

Most field crops currently using border or furrow irrigation methods could be irrigated with some type of sprinkler system. Sprinkler systems require more capital than nonpressurized systems but are more efficient in water application, require less labor and, with good management, will reduce tailwater substantially.

The cost of restricting tailwater losses from a 170 acre tomato field was estimated by comparing the costs of a conventional furrow irrigation system with three systems that essentially eliminate tailwater. They are a furrow irrigation operation using gated pipe and a reuse system, a handmove sprinkler system and a side roll sprinkler system.

The conventional furrow irrigation system utilized earth head ditches, canvas dams and 1-1/2 inch siphons. The field was leveled annually and the cost per acre of irrigating the tomato crop was $177.21 (Table 1). No reuse system was employed and five acre-feet of water per acre was applied to the crop.

The second system was also a furrow system, but instead of earth head ditches, gated pipe was utilized with a settling pond and a reuse pump. The total amount of water used was reduced from five acre-feet to 3.75 acre-feet per year. This reduction in water use was measured on a 170 acre tomato field located in the Panoche Water District. The amount and quality of water applied, tailwater and water reuse were monitored in 1975. The tailwater, as a percent of applied water, was 28.7 percent for the field and 24 percent for a specific 63 furrow section of the field (Tanji, 1976, p. 84). Therefore, the water recovery factor of 25 percent was used in calculating costs for this system. Limited resources and errors in other monitoring efforts prevented replicating these measurements as planned. However, these results seem to be within the observed limits of other reuse systems.

The cost of irrigating the tomato field with this system was $150.25, or almost $27.00 less than the conventional furrow system. Investment per acre increased from $7.74 to $249.00 per acre and labor decreased from $135 to $90 per acre.

The cost of irrigating the tomatoes by the hand move sprinklers was $152.21. Although the capital requirements were less than the gated pipe-reuse system, operating costs were slightly higher.

The side roll sprinkler system resulted in costs of $127.79 per acre. Capital requirements were high compared to the other systems but only one hour of labor per acre per irrigation is needed to operate the system. This is considerably less than the other irrigation methods considered.

TABLE 1

Summary of Irrigation Costs per acre for
170 acres of Tomatoes by Irrigation Method
Panoche Water District, 1976

	Furrow with Siphons and no Reuse System	*Furrow with Gated Pipes and Reuse System*	*Side Roll Sprinkler*	*Hand Move Sprinkler*
		Dollars Per Acre		
Investment	7.74	249.00	291.37	165.58
Depreciation[2]	.65	9.97	19.39	10.98
Interest	.31	9.96	11.67	6.63
Taxes	.16	4.98	7.83	3.33
Total Overhead	1.12	24.91	38.89	20.94
Operating Costs:				
Irrigation Preparation	10.76	9.38	– –	– –
Water Requirement	5.00AF	3.75AF	3.75AF	3.75AF
Water Cost	30.00	22.50	22.50	22.50
Labor ($4.50/hr.)	135.00[1]	90.00	45.00[1]	90.00[1]
Repairs	.33	.34	11.65	6.64
Power	– –	3.12	10.34	9.35
Lateral Installation and Removal	– –	– –	1.41	2.78
Total Operating Cost	176.09	125.34	90.90	131.27
Total Cost	177.21	150.25	127.79	152.21

[1] Reed, A. D., Jewell L. Meyer and Falih K. Aljibury, "Irrigation Costs," Cooperative Extension University of California, Leaflet 2875, Davis, Aug. 1976.

[2] An 8 percent interest rate and straight line depreciation was used. Specific cost budgets are presented in the appendix.

These data indicate that irrigation systems designed to apply water efficiently and without the production of significant tailwater is also the least-cost alternative. These results probably could be achieved in most other areas of the Central Valley because the physical conditions in the test area are fairly representative. The cost of water used in this analysis was $6.00 per acre-foot which is relatively cheap. The higher the cost of water the greater the cost savings from using the more water efficient systems. If water were free, a conventional furrow system would compare more favorably with the more efficient systems, but the high labor requirement of operating siphons and canvas dams result in high operating costs.

The internal rate of return was approximated for the three irrigation systems that are capable of controlling tailwater. The savings in irrigation costs as a result of using the three systems was used as the annual return. The internal rate of return for the gated pipe and reuse system was approximately 18 percent; the side roll sprinkler system, 16 percent; and the hand move sprinkler system, 16.5 percent. The investment in more efficient irrigation systems appears to be profitable. However, a relatively few California irrigators have adopted field recycle systems or sprinkler irrigation systems. The reasons farmers have not widely adopted field recycle systems may be a topic of further research.

MANAGEMENT OF DRAINAGE WATER AT THE FARM LEVEL

The problem of managing irrigation return flows in the San Joaquin Valley is complicated by high water table conditions in many locations (San Joaquin Valley Interagency Drainage Program). In the Panoche Soil Conservation District, water table elevations have been rising steadily for a number of years (Stoddard & Kaner). The Enrico farm, located within this district, has been recycling a mixture of surface runoff and subsurface tile drainage water since 1969. A normative linear programming analysis was developed based on the actual operations of the Enrico farm. The objective of the LP problem is to derive cropping patterns and water use that maximize returns to land and management for the model farm, subject to restraints on crop rotation, quantity and quality of applied water, and resource availability.

Model Formulation

The Enrico farm is 1,675 acres in size with an entitlement to 5025 acre-feet of district water. District water is taken from the supply canal near the lower end of the farm where it may be mixed with return-flows before the mixture is pumped to the upper end for application. The quality of applied water can be varied by using different proportions of project and recycled water.

The surface and subsurface return-flows are collected in a District drainage ditch located on the farm's boundary. In addition, due to uphill discharges into this drain, the farm has access to additional drainage water for recycling purposes. In order to represent a variety of conditions for available uphill runoff, the model was run with levels ranging from 0 to 3000 acre-feet.

Gross revenues for cropping activities were determined using area average prices and yields from the period 1970 to 1976. Net revenues were then derived by subtracting typical crop production costs (University of California Cooperative Extension). Water activities were defined for the application of project and recycled water. The costs of running these activities were then subtracted from crop revenues in the objective function. The cost of pumping return-flows back to the fields was assumed to be $3.50 per acre-foot. Model solutions were derived using a range of prices for project water, varying from $5.00 to $25.00 per acre-foot.

Crop alternatives include tomatoes, wheat, barley, cotton, alfalfa seed, sugar beets, and dry beans. The crops were separated into three classes according to their yield tolerance to the boron concentration of applied water (University of California Committee of Consultants). For each boron tolerance level, limits are set on the maximum proportion of return-flows in applied water that will avoid yield reductions. These limits are based on flow-weighted average boron concentrations as measured on the Enrico farm during the 1975 and 1976 irrigation seasons. District water had a flow weighted average boron concentration of 0.1 mg/l, compared to about 2.5 mg/l for recycled water. Total dissolved solids of these waters were low. Therefore, considering the boron tolerance of crops was sufficient in determing the yield reduction from TDS (University of California Committee of Consultants) solutions were also derived using an assumed boron concentration of 10 mg/1 in drainage water, to reflect conditions where the subsurface component was a higher proportion of total return-flows.

Water application and runoff rates are based on values estimated by the California Department of Water Resources. Maximum acreage rectrictions were included to reflect rotational and crop contract requirements.

Model Results

Optimal project and drainage water use, cropping patterns and returns per acre for the farm were derived for various water prices and amounts of external drainage water supplied (Table 2). Assuming a $5.00 District water cost and 3,000 acre feet of district return flows, drainage water use was 3,382 acre-feet, or 68 percent of total water use. If a $20.00 District water cost is assumed, the amount of drainage

TABLE 2

Optimal Cropping Pattern and Drainage Water Use with Zero, 1,000 and 3,000 Acre-Foot of Drainage Water Available and Project Water Costing $5.00 and $20.00 per Acre-Foot. Enrico Brother's Farm, Panoche Irrigation District.

	District Water Costs/Acre-Foot					
	$5.00	*$20.00*	*$5.00*	*$20.00*	*$5.00*	*$20.00*
Drainage Water Available (Acre-Foot)	3,000	3,000	1,000	1,000	0	0
Drainage Water Use (Acre-Foot):						
High Quality Blend	1,000	1,000	633	1,101	0	1,101
Medium Quality Blend	1,777	1,169	1,777	1,309	1,410	309
Low Quality Blend	607	2,180	380	380	380	380
Total	3,382	4,349	2,790	2,790	1,790	1,790
Percent of Total Water Use	68	76	57	57	37	37
Drainage Water Discharged	1,363	396	0	0	0	0
Project Water Use (Acre-Foot):						
High Quality Blend	1,000	1,000	1,570	1,101	2,203	1,101
Medium Quality Blend	523	344	523	991	890	1,991
Total	1,523	1,344	2,092	2,092	3,092	3,092
Total Water Applied (Acre-Foot)	4,905	5,693	4,882	4,882	4,882	4,882
Cropping Pattern (acres):						
Tomatoes	500	500	500	500	500	500
Wheat	600	75	600	600	600	600
Cotton	400	400	400	400	400	400
Alfalfa Seed	75	600	0	0	0	0
Sugar Beets	100	100	100	100	100	100
Dry Beans	0	0	75	75	75	75
Total	1,675	1,675	1,675	1,675	1,675	1,675
Returns Per Acre	336	322	335	316	334	306

water used for irrigation increased to 4,349 acre-feet, or 76 percent of total water use. Average returns decreased from $336 to $322 per acre, as a result of the higher cost of water and the change in the cropping pattern from wheat to alfalfa seed which has a higher tolerance to boron. Total water application increased from 4,905 to 5,693 acre-feet.

If external drainage water supplies are decreased below 3,000 acre-feet, changes in project water costs do not affect the amount of drainage water reused. With 1,000 and zero acre-feet of extra drainage water available, respectively, 57 percent and 37 percent of the total applied water is composed of drainage water. This represents total reuse of farm and off-farm return-flows.

CONCLUSIONS

The amount of field tailwater can be reduced significantly and the annual costs of irrigation slightly reduced by adopting reuse or sprinkler application systems. However, the high capital requirements of $165 to $300 per acre may prevent the adoption of such techniques. For example, installing a hand move sprinkler system or a side roll system on 160 acres would require $26,540 and $46,620, respectively. Although the annual irrigation costs are lowered with these systems, the purchase of such a system may not be the optimal investment if capital is limited. Greater returns may be realized from investment in land or machinery. More efficient use of irrigation water would also result if water prices were increased, or the quantity of water decreased.

The profitability of augmenting the farm water supply with drainage water depends on the costs of both District water and recycle system. Generally, the higher the cost of irrigation water the greater the value of drainage water. Assumming a $20.00 cost of irrigation water, returns could be increased by $16.00 per acre by pumping an additional 2,604 acre-feet of drainage water from the District's drainage canal. The optimal water supply would consist of 75 percent drainage water. At a $5.00 water cost about 68 percent of the optimal irrigation water supply would be drainage water.

APPENDIX

TABLE A-1

Per Acre Cost of Furrow Irrigating a 170 Acre Tomato Field with Siphons and No Reuse System.

				Annual Cost			
	Cost	*Cost Acre*	*Life*	*Depreciation*	*Interest*	*Taxes*	*Total*
Investment						*Dollars Per Acre*	
Pitcher, 54"	2,100	2.63	20	.13	.11	.05	.29
Siphons, 1½-300	475	1.36	10	.14	.05	.03	.22
Canvass, 12	350	1.00	5	.20	.04	.02	.26
Ditch Closer	2,200	2.75	15	.18	.11	.06	.35
Total Overhead		7.74		.65	.31	.16	1.12
Operating Costs:							
Irrigation Preparation:							
Fuel and Repairs				6.02			
Labor (.75/Acre)				3.36			
Total Leveling					9.38		
Ditch Open & Close:							
Fuel & Repairs				.82			
Labor (.12/Acre)				.54			
Total Ditch Costs					1.36		
Total Irrigation Preparation						10.76	
Irrigation: (10X)							
Labor (30 hours/acre)				135.00			
Water (5 Acre-Foot)				30.00			
Repairs				.33			
Total Irrigation						165.33	
Total Operating Costs							176.09
Total Irrigation Cost							177.21

TABLE A-2

Per Acre Cost of Furrow Irrigating a 170 Acre Tomato Field with Gated Pipe and a Reuse System.

				Annual Cost			
	Cost	Cost Acre	Life	Depreciation	Interest	Taxes	Total
Investment:				*Dollars Per Acre*			
PVC Pipes:							
15"	10.560	66.00	30	2.20	2.64	1.32	6.16
10" or 12"	3,300	21.00	30	.70	.84	.42	1.96
Gated Pipes	18,744	117.00	30	3.90	4.68	2.34	10.92
Pump[1]	4,000	25.00	10	2.50	1.00	.50	4.00
Settling Pond[1]	3,250	20.00	30	.67	.80	.40	1.87
Total		249.00		9.97	9.96	4.98	24.91
Operational Costs:							
Irrigation Preparation:							
Leveling:							
Fuel and Repairs			6.02				
Labor (.75/Acre)			3.36				
Total Irrigation Preparation					9.38		
Irrigation: (10X)							
Labor (20.00 hours/acre)			90.00				
Water (3.75 (Acre Foot)			22.50				
Power for Recirculation			3.12				
Fuel & Repairs			.34				
Total Irrigation					115.96		
Total Operating							125.34
Total Irrigation Costs							150.25

[1] Source: Ray Ram, Manager, Panoche Irrigation District, Firbaugh CA.

TABLE A-3

Per Acre Cost of Irrigating a 170 Acre Tomato Field with a Side Roll Sprinkler System

	Annual Cost						
	Cost	*Cost Acre*	*Life*	*Depreciation*	*Interest*	*Taxes*	*Total*
Investment:	*Dollars Per Acre*						
Aluminum Pipe:							
10"	4,642.70	27.31	15	1.82	1.09	.54	3.45
8"	3,478.20	20.46	15	1.36	.82	.41	2.59
Hydrant Valves	535.50	3.15	20	.16	.13	.06	.35
Pump	10,062.50	62.50	15	4.17	2.50	1.25	7.92
Laterals	30,395.00	178.13	15	11.88	7.13	3.57	22.58
		291.37		19.39	11.67	5.83	36.89
Operating Costs:							
Irrigation (10X)							
Labor (10. hours/acre)			45.00				
Water (3.75 AF)			22.50				
Power			10.34				
Repairs (4%)			11.65				
Total Irrigation					89.49		
Lateral Installation & Removal:							
Fuel & Repair			.71				
Labor			.70				
Total Lateral Installation & Removal					1.41		
Total Operating Costs							90.90
Total Irrigation Costs							127.00

TABLE A-4

Per Acre Cost of Irrigating a 170 Acre Tomato Field with a Hand Move Sprinkler System

				Annual Cost			
	Cost	*Cost Acre*	*Life*	*Depreciation*	*Interest*	*Taxes*	*Total*
Investment:				*Dollars Per Acre*			
Aluminum Pipe:							
10"	4,642.70	27.31	15	1.82	1.09	.55	3.46
8"	3,478.20	20.46	15	1.36	.82	.41	2.59
Hydrant Valves	814.30	4.79	20	.24	.19	.10	.53
Pump	10,062.50	62.50	15	4.17	2.50	1.25	7.92
Laterals	8,639.40	50.82	15	3.39	2.03	1.02	6.44
		165.88		10.98	6.63	3.33	20.94
Operating Costs:							
Irrigation (10X)							
Labor (20 hours/acre)			90.00				
Water (3.75 AF)			22.50				
Power			9.35				
Repairs (4%)			6.64				
					128.49		
Lateral Installation & Removal:							
Fuel & Repairs			1.40				
Labor			1.38				
Total Lateral Installation & Removal				2.78			
Total Operating Costs							131.27
Total Irrigation Costs							152.21

REFERENCES

1. Tanji, K. K., J. W. Biggar, G. L. Horner, R. J. Miller, and W. O. Pruitt, "Irrigation Tailwater Management" First Annual Progress Report for EPA Grant No. R 803603-01-1, U. C., Davis, Water Science and Engineering Paper 4011, April, 1976.

2. Reed, A. D., Jewell L. Meyer and Falik K. Aljibury, "Irrigation Costs", University of California Cooperative Extension, Leaflet 2875, Davis, Aug. 1976.

3. California Department of Water Resources, *Vegetative Water Use in California, 1974*, Bulletin No. 113-3, The Resources Agency, State of California, April, 1975.

4. Ayers, Robert S., and Roy L. Branson, "Water Quality Guidelines for Interpretation of Water Quality for Agriculture", University of California Cooperative Extension, January 15, 1975.

5. San Joaquin Valley Interagency Drainage Program, Program Review Report, U.S. Bureau of Reclamation, California State Water Resources Control Board, March, 1976.

6. Stoddard Howard and Henry Karrer, "Drainage Investigation and Master Drainage Plan Panoche Conservation District", Stoddard and Karrer Civil Engineers, Los Banos, June, 1968.

Managing Saline Water for Irrigation

Proceedings of the International Conference on Managing Saline Water for Irrigation: Planning for the Future

Edited by

H. E. Dregne
Horn Professor and Director, International
Center for Arid and Semi-Arid Land Studies,
Texas Tech University

Sponsored by

Subcommission on Salt-Affected Soils, International Society of Soil Science
Soil Science Society of America
New Mexico State University
Texas A&M University
Texas Tech University
U.S. Environmental Protection Agency
U.S. Salinity Laboratory

Organizing Committee

H. E. Dregne, Texas Tech University, chairman
A. G. Hornsby, U.S. Environmental Protection Agency
J. van Schilfgaarde, U.S. Salinity Laboratory
C. W. Wendt, Texas A&M University
P. J. Wierenga, New Mexico State University

A CONCEPTUAL HYDROSALINITY MODEL FOR PREDICTING SALT LOAD IN IRRIGATION RETURN FLOWS

Kenneth K. Tanji[1]

INTRODUCTION

Under the Federal Water Quality Pollution Control Act of 1972 and its Amendments (Federal Register, 1972), the U. S. Environmental Protection Agency has a statutory charge to control point-source discharges of pollutants, including agricultural runoff, to navigable waters, For irrigated agriculture, there is a need to identify both the level of management required to achieve pollution control goals and the kinds of data and information that are required to evaluate irrigation return flows. The dissolved mineral salt load in return flows from irrigated agriculture and its control are regarded as the major, if not the most important, water-quality problem in semiarid regions of the United States (for example, Ayers and Coppock, 1974) and elsewhere.

Comprehensive, dynamic hydrosalinity simulation models are being formulated and some of them have been applied to large-scale systems but most of them are not widely used for a variety of reasons, including the costs involved, requirement of an extensive input data base, and difficulties in verifying model outputs. For these and other reasons, the need is urgent for a "best-estimate methodology" using best available information and judgment.

Presented herein is a description and applications of a steady-state conceptual hydrosalinity model. The model may serve as a first-order approximation in lieu of more detailed and refined models for evaluating mass emission of salts from irrigated agriculture.

---

[1] Department of Land, Air and Water Resources, Water Science and Engineering Section, University of California, Davis.

MODELING PRINCIPLES AND OBJECTIVES

The analysis of the flow of water and salts in irrigated agriculture is admittedly very complex, usually requiring computer modeling and simulations (Hornsby, 1973), but such models are available for only a comparatively small number of river basins and irrigation projects. An interim solution using the "best-estimate methodology" is proposed.

It is presumed that mass emission of salts from irrigated lands could be controlled to a great extent with irrigation efficiencies that provide adequate water to meet the evapotranspiration needs of crops and salt control in crop root zones. This implies that the quantity of water used may be minimized with due allowances for attainable on-farm irrigation application efficiencies and project distribution efficiencies, salt control measures for the most sensitive crops grown in the area, current limitations on delivery and size of stream, and the capture of usable irrigation return flow.

The approach taken in the proposed model simplifies the "real-world" complexities to circumvent the constraint of the lack of a detailed field data base and to take advantage of the best available information and judgment. The time scale chosen is an irrigation season. This model is applicable to large tracts of land such as an irrigation project, and may not have the resolution for smaller-scale systems.

The conceptual model is based upon two major underlying principles: conservation of mass and steady state. Mass balance is invoked for both water and salts so that quantitative estimates could be made. Steady-state conditions are assumed to reflect long-term rather than short-term trends.

The hydrosalinity model focuses on the crop root-zone portion of the irrigated agriculture system. It attempts to consider only the main flow pathways of water and salts, with some considerations for sinks and sources and initial conditions. Input data requirements and model coefficients that are not readily available can be estimated from experience and judgment or translated from other similar projects, so that there will be no constraints placed on the application of the model to most areas.

This methodology has requisite characteristics to evaluate water management and practices, irrigation water quality, and soil properties that affect salt load in irrigation return flows. Its output could be used as input to other models dealing with stream, lake, and groundwater systems. It could be used to appraise not only the current and historical hydrologic and salinity conditions, but also to estimate anticipated changes in water and salt flows if certain management practices are modified.

DESCRIPTION OF THE IRRIGATION AGRICULTURE SYSTEM

The irrigated agriculture system is simplified to evaluate salt emission and controls without resorting to finely-tuned dynamic simulation models. It is possible that in generalizing this system, with a focus on the crop root zone, site-specific exceptions may arise. Such exceptions should be incorporated with pertinent modifications to the mathematical model described in detail in the Appendix.

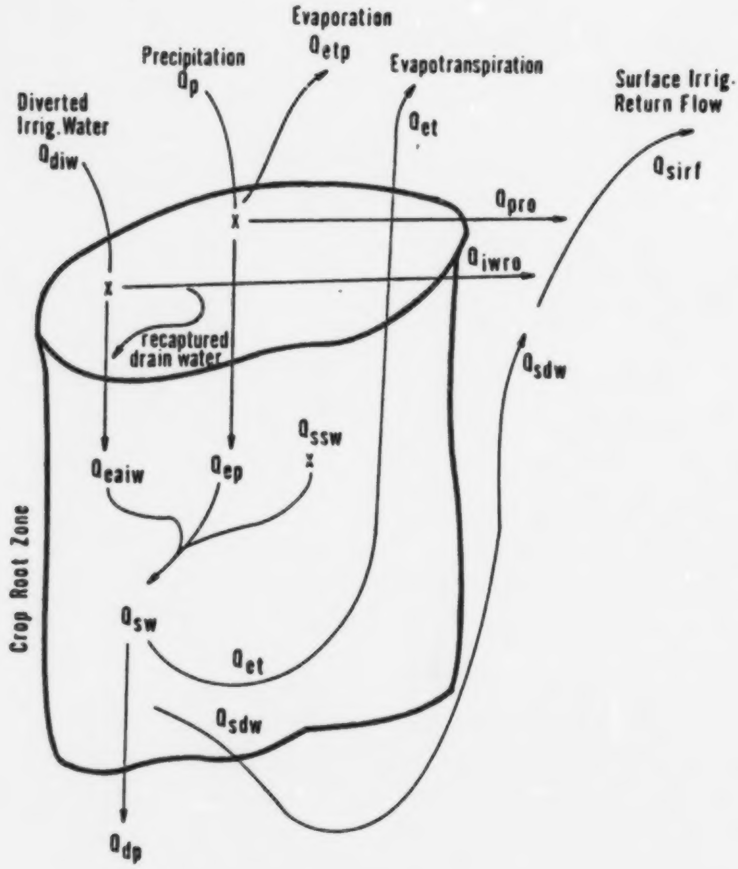

Evaporation
Q_{etp}
Precipitation
Q_p
Evapotranspiration
Q_{et}
Surface Irrig. Return Flow
Q_{sirf}
Diverted Irrig. Water
Q_{diw}
Q_{pro}
Q_{iwro}
recaptured drain water
Q_{sdw}
Q_{ssw}
Q_{eaiw}
Q_{ep}
Crop Root Zone
Q_{sw}
Q_{et}
Q_{sdw}
Q_{dp}

Figure 1. A conceptual view of water flow in the crop root zone portion of the system irrigated agriculture. The symbol Q refers to quantity of water. Definition of subscripts are given in the Appendix.

Figure 1 schematically gives the hydrologic inputs and outputs, and their flow pathways. The symbol Q denotes quantity of water (ha-m, ac-ft) obtained from the product of surface area (ha, ac) and unit water flow (ha-m/ha, ac-ft/ac) for the irrigation season. The inputs include precipitation (Q_p), and diverted irrigation water (Q_{diw}) from all sources during the irrigation season. Stored soil water (Q_{ssw}) from the nonirrigation season is a source. The outputs include evapotranspiration (Q_{et}, Q_{pet}), surface runoff (Q_{iwro}, Q_{pro}), deep percolation (Q_{dp}), and collected subsurface drainage (Q_{sdw}) from underdrains, interception by open drains, drainage wells, etc. The sum of Q_{sdw}, Q_{iwro}, and Q_{pro} is collectively referred to as surface irrigation return flow (Q_{sirf}). The mass inflow of water to the crop root zone is made up of effective applied irrigation (Q_{eaiw}), effective precipitation (Q_{ep}) and stored soil water (Q_{ssw}).

Figure 2 shows the corresponding salt inputs and outputs, and their flow pathways. The salinity parameter (C) used herein is total dissolved solids (TDS) in mg/liter. The mass (tonnes, tons) of dissolved salts (M) is the product of the salt concentration, the volume of water, and an appropriate conversion factor. Provisions have been made for salt pickup in surface runoffs (C_{iwrosp}, C_{prosp}). The TDS of soil water (C_{sw}) is the volume-weighted average of effective applied irrigation water, effective precipitation, and stored soil water.

The soil water (Q_{sw}) is subject to concentration in volume due to evapotranspiration losses. This degree of volume concentration is designated ETCF. In addition, provisions have been made to include the tendency of the applied water to pickup salts (M_{sp}) or to deposit salts (M_{sd}) as it is concentrated in the soil solution. This mineral dissolution-mineral precipitation phenomena is partly accounted for by the effects of irrigation water quality and leaching fraction (Rhoades et al., 1973). In addition, the contribution of dissolved salts by excess native soil gypsum when present is empirically considered. The final concentration of salts in the root zone after evapotranspiration and salt pickup-salt deposition is C'_{sw}.

It is assumed that the TDS of deep percolation and subsurface drainage is identical to C'_{sw}. The salt concentration in the surface irrigation return flow (C_{sirf}) is the volume-weighted average of collected subsurface and surface runoff components.

If steady-state conditions are assumed, there will be no change expected with time within the study period (irrigation season, hydrologic year, crop rotation period, etc.) in contrast to nonsteady-state or dynamic conditions. Also, if conservation of mass is invoked the outputs of water and salts will be balanced by the inputs and sources and sinks. Where irrigation is not practiced year-round and significant precipitation occurs between irrigation seasons, initial conditions such as stored soil water should be

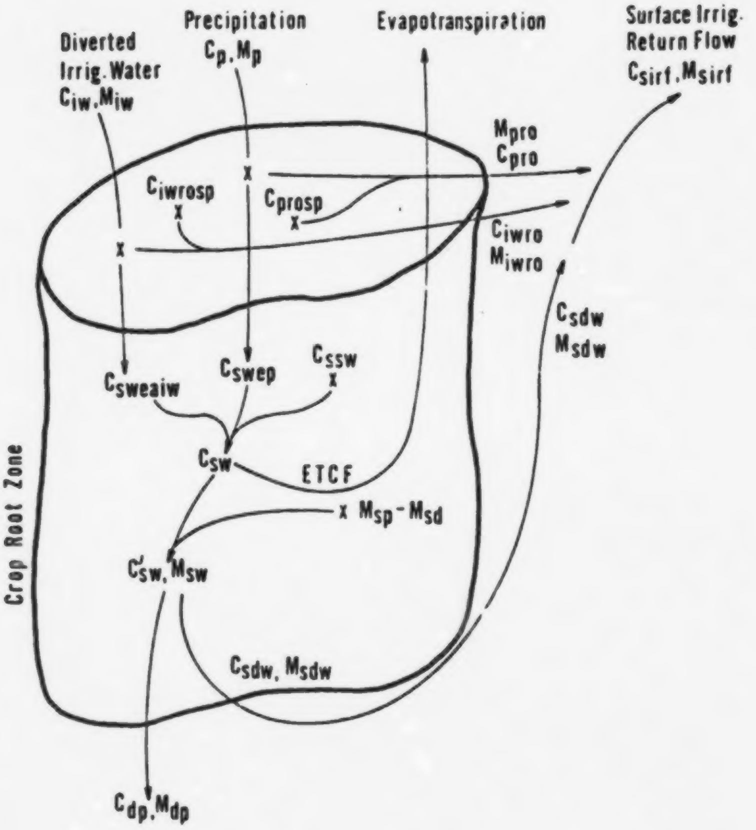

Diverted Irrig. Water
C_{iw}, M_{iw}
Precipitation
C_p, M_p
Evapotranspiration
Surface Irrig. Return Flow
C_{sirf}, M_{sirf}
M_{pro}
C_{pro}
C_{iwrosp}
C_{prosp}
C_{iwro}
M_{iwro}
C_{sdw}
M_{sdw}
C_{sweaiw}
C_{swep}
C_{ssw}
C_{sw}
ETCF
$M_{sp} - M_{sd}$
C'_{sw}, M_{sw}
C_{sdw}, M_{sdw}
Crop Root Zone
C_{dp}, M_{dp}

Figure 2. A conceptual view of salt flow in the crop root zone portion of the system irrigated agriculture. The symbols C and M respectively, denote concentration (TDS) and mass (tonnes) of salts. Definition of subscripts are found in the Appendix.

considered. However, if irrigation is practiced year-round, then it is assumed that stored soil water would be the same at the beginning and at the end of the study period, and it could be neglected.

This model does not consider rim inflows from contiguous areas. Such rim inflows may consist of both surface and subsurface origins, including surface runoff, interflow, rising groundwaters, etc. Water percolating past the root zone is split into two streams, subsurface drainage and deep percolation, which usually can only be guess-estimated in the absence of adequate hydrogeologic characterization. Space-averaging over the study area and time-averaging over the study period are necessary for all model parameters and coefficients.

MODEL CALIBRATION AND VERIFICATION

To obtain credibility the model should be first calibrated with present and/or historical data. In this particular case, the calibration procedure involved the fitting of calculated flow (volume) and TDS of surface irrigation return flows from Glenn-Colusa Irrigation District (GCID) with measured data from the 1973 irrigation season. This was then followed by verification which involved predicting present and/or historical data other than the one used for calibration, for example, the 1970 irrigation season. A comparison between predicted and measured results in the verification step gives some estimate of the validity of the model for that particular system.

Figure 3 gives the general location map where this model was applied in California. Figure 4 is a map of the 66,298 ha Glenn-Colusa Irrigation District which obtains its supply water by diverting Sacramento River water near Hamilton City and from Stony Creek. The main supply distribution canal runs along the district's western boundary. Surface irrigation return flows are conveyed in 11 lateral drains and collected in the Colusa Basin Drain. Flooded rice is the major crop in GCID, occupying 66 and 71% of the total irrigated acreage in 1973 and 1970, respectively. This district captured drain water equal to 23 and 29%, respectively of the total diversions in 1973 and 1970. The climate is of the Mediterranean type with a mean annual precipitation of 0.44 m. The irrigation season starts in April and ends in October.

Table 1 lists the required input parameters and coefficients for the conceptual model. The details of the computational procedure are given in the Appendix. The major sources of information were GCID'S Annual Report (1974) on Water Measurement Program for 1973, the California Department of Water Resources bulletin on Vegetative Water Use (1967, 1975) and our own water quality survey (Low et al., 1974) in this district.

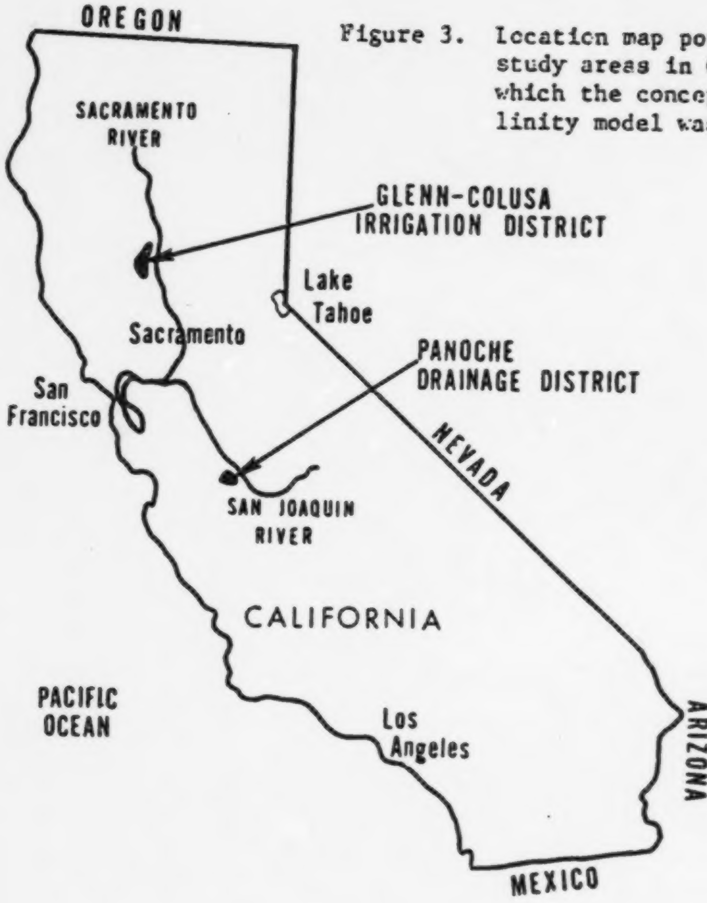

OREGON
SACRAMENTO RIVER
GLENN-COLUSA IRRIGATION DISTRICT
Lake Tahoe
Sacramento
PANOCHE DRAINAGE DISTRICT
San Francisco
NEVADA
SAN JOAQUIN RIVER
CALIFORNIA
PACIFIC OCEAN
Los Angeles
ARIZONA
MEXICO

Figure 3. Location map pointing out two study areas in California to which the conceptual hydrosalinity model was applied.

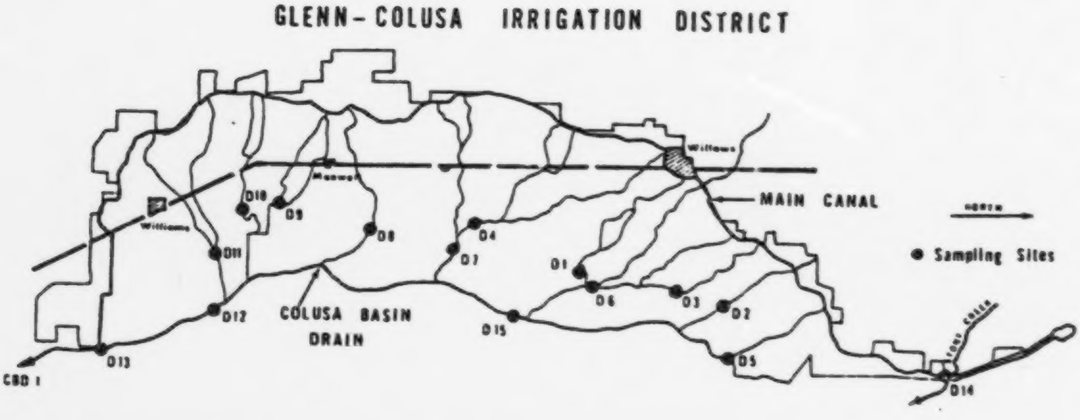

GLENN-COLUSA IRRIGATION DISTRICT
Willows
Maxwell
Williams
MAIN CANAL
NORTH
● Sampling Sites
D10
D9
D8
D11
D4
D7
D1
D6
D3
D2
D12
COLUSA BASIN DRAIN
D15
D5
D13
CBD 1
D14

Figure 4. Map of the 66,400 ha Glenn-Colusa Irrigation District in the Sacramento Valley.

Table 1. Required Input Data and Model Coefficients*

Parameters and Coefficients	Calibration 1973 GCID	Verification 1970 GCID	Applicatio 1975 PDD
Total Land Area (A), ha	66,298	66,298	17,724
Diverted Irrigation Water (Q_{diw}), ha-m	99,059	92,389	18,076
Irrigation Application Efficiency, (E_{iae})	0.80	0.80	0.75
Precipitation (Q_p), ha-m	3,095	1,850	2,698
Precipitation Runoff Coefficient (a)	0.2	0.2	0.2
Precipitation Evapotranspiration Coefficient (b)	0.7	0.7	0.7
Effective Precipitation Coefficient (c)	0.1	0.1	0.1
Stored soil Water (Q_{ssw}), ha-m+	1,486	8,318	--
Water Holding Capacity of Soil (D_{whc}), m/m	0.09	0.09	--
Average Rooting Depth (D_r), m	0.76	0.76	--
Stored Soil Water Coefficient (d)	1.0	0.56	--
Evapotranspiration (Q_{et}), ha-m	6,104	6,104	--
Potential Evapotranspiration (Q_{pet}), ha-m/ha	1.02	1.02	1.25
Evapotranspiration Coefficient (e)	0.9	0.9	0.4
Deep Percolation Coefficient (f)	0.8	0.8	0.7
TDS of Diverted Water (C_{iw}), mg/ℓ	91	99	234
Salt Pickup by Runoff (C_{iwrosp}), mg/ℓ	5	5	35
TDS of Precipitation (C_p), mg/ℓ	10	10	10
Salt Pickup by Runoff (C_{prosp}), mg/ℓ	5	5	35
Salt Pickup-Salt Deposition ($M_{sp}-M_{sd}$), tonnes	121,777	102,471	58,824
Gypsum Contribution, tonnes/ha-m water	0	0	21.48

* Numerical values given are for model calibration and verification for Glenn-Colusa Irrigation District using the 1973 and 1970 irrigation season, and application to Panoche Drainage District for the 1975 calendar year.

+ Not required, but given for informational purposes.

The numerical data given for the required input data and coefficients are the final ones used for calibration for the 1973 irrigation season. This calibration was obtained with three iterations in attempting to fit the calculated flow and TDS of surface irrigation return flows to that of monitored values. The only two coefficients which were adjusted in the calibration process were the deep percolation coefficient (f) and the irrigation application efficiency (E_{iae}).

Table 2 gives the results of the final calibration run. It was possible to obtain outputs on irrigation return flow that were within ±2% of the observed data.

The calibrated model was then applied to the 1970 irrigation season for model verification. Table 1 contains the required input parameters for 1970. The only input data different in 1970 are diverted water, precipitation during growing season, stored soil water from winter nonirrigation season, and TDS of supply water (GCID, 1971). All other model parameters and coefficients were identical to the calibration run. Figure 5 gives a plot of salt pickup-salt deposition as related to leaching fraction. The data points for Feather River water came from van Schilfgaarde et al. (1974), based on consumptive use of 0.91 m/yr. The other two curves are, at best, estimates for the Sacramento River water (supply water for GCID) and the Delta-Mendota Canal water (supply water for Panoche Drainage District). All three waters have a negative saturation index (Langelier, 1936), which indicates that these waters have a tendency to dissolve calcium carbonate upon contact.

Table 2 reports the results of model verification. It appears that the model can only predict to within ±33% of observed values. These results, however, are acceptable, considering the simplifying assumption made in the model and the fact that 1970 was a normal year (0.461 m precipitation from November, 1969 through October, 1970) as compared to 1973 (0.677). Table 3 contains a partial listing of various outputs from the 1973 calibration and 1970 verification runs.

MODEL APPLICATION

The calibrated and verified model was applied to a second irrigation project to further test the utility of this approach and to consider an area containing salt-affected soils (Figs. 3 and 6). The Panoche Drainage District (PDD), comprising of four irrigation districts, is located in the San Joaquin Valley and obtains its supply water from two imported sources: Delta-Mendota Canal and the California Aqueduct. The drain waters from the 17,724 ha PDD are collected in several canals and discharged into the Panoche Drain (Station I-6

Table 2. Results of Model Calibration and Verification on Glenn-Colusa Irrigation District for the 1973 and 1970 Irrigation Season (April-October) respectively.

Parameter	Measured	Calculated	Difference
Calibration (1973)			
Surface Irrigation Return Flow, ha-m	26,583	27,112	+2.0%
TDS of Return Flow, mg/ℓ	220	215	-2.3%
Salt Mass in Return Flow, tonnes	58,522	58,328	-0.3%
Verification (1970)			
Surface Irrigation Return Flow, ha-m	34,512	23,127	-33.0%
TDS of Return Flow, mg/ℓ	192	236	+22.9%
Salt Mass in Return Flow, tonnes	66,305	54,614	-17.6%

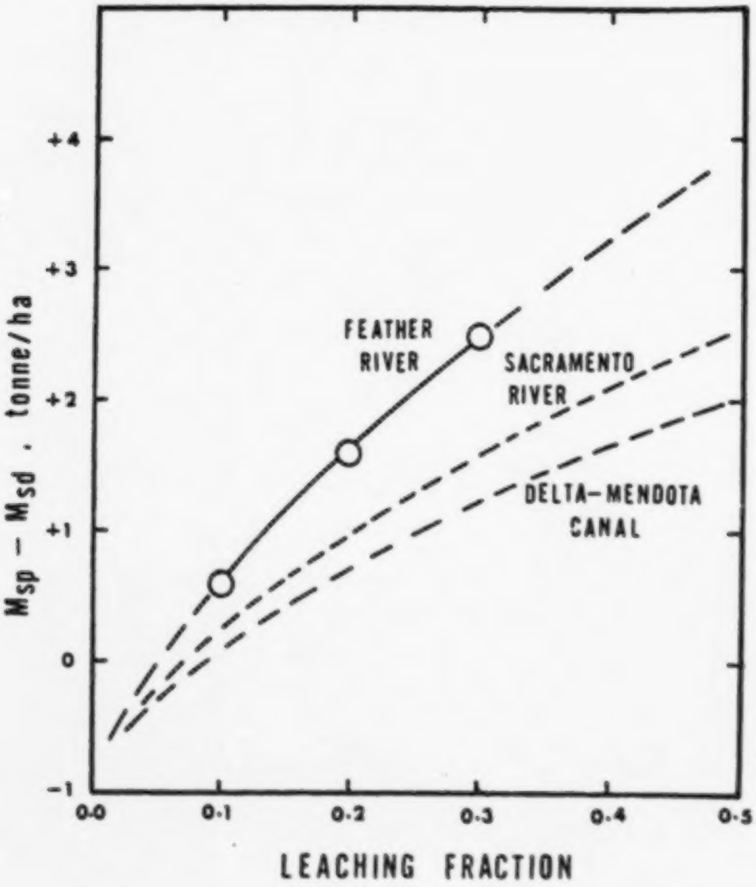


Figure 5.

Relations between salt pickup-salt deposition from applied irrigation waters and leaching fraction.

Table 3. Partial Summary of Calibration and Verification Outputs for Glenn-Colusa Irrigation District for the 1973 and 1970 Irrigation Seasons, Respectively

Parameter	1973	1970
Diverted Irrigation Water, ha-m/ha	1.49	1.39
Irrigation Application Efficiency	0.80	0.80
Irrigation Efficiency	0.53	0.60
Leaching Fraction	0.35	0.26
Leaching Beyond Root Zone, ha-m/ha	0.50	0.32
Deep Percolation, ha-m/ha	0.40	0.26
Subsurface Drainage, ha-m/ha	0.10	0.06
Irrigation Runoff, ha-m/ha	0.30	0.28
Precipitation Runoff, ha-m/ha	0.01	0.006
Surface Irrigation Return Flow, ha-m/ha	0.41	0.35
ET Concentration Factor of Soil Water	2.83	3.85
TDS of Soil Water after ET, mg/ℓ	221	346
Salt Pickup-Salt Deposition, tonnes/ha	1.84	0.63
Final TDS of Soil Water, mg/ℓ	585	825
TDS of Surface Irrigation Return Flow, mg/ℓ	215	236

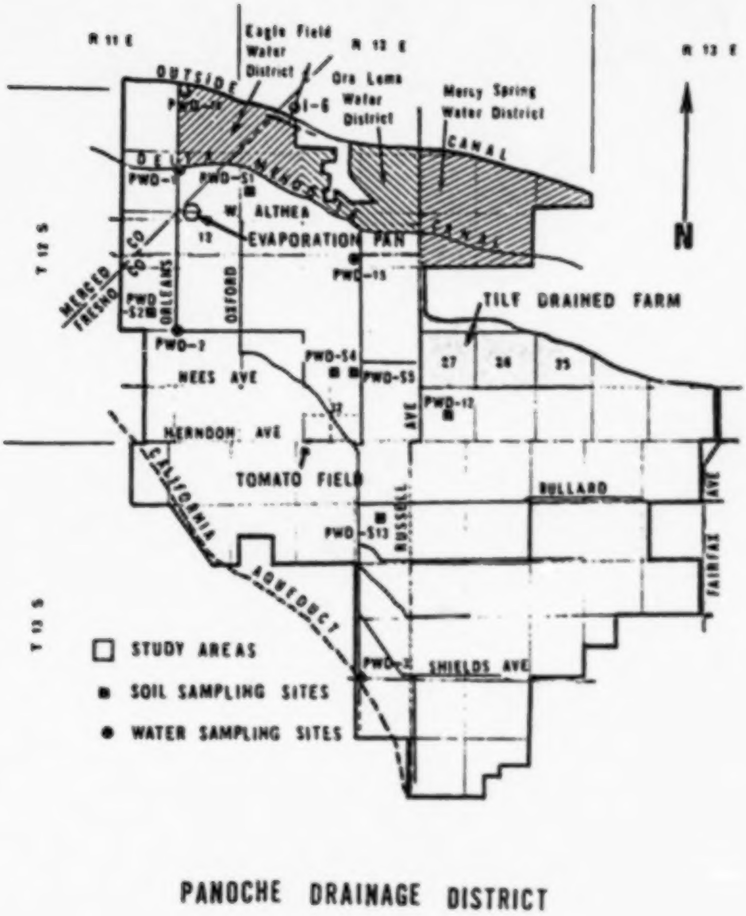

R 11 E
Eagle Field Water District
R 12 E
Oro Loma Water District
Mercy Spring Water District
R 13 E
OUTSIDE
CANAL
DELTA MENDOTA CANAL
PWD-11
I-6
PWD-1
PWD-S1
W. ALTHEA
12
EVAPORATION PAN
N
T 12 S
MERCED CO
FRESNO CO
PWD-15
TILE DRAINED FARM
PWD-S2
ORLEANS
OXFORD
PWD-2
PWD-S4
PWD-S5
27
26
25
NEES AVE
32
PWD-12
AVE
HERNDON AVE
CALIFORNIA AQUEDUCT
TOMATO FIELD
RUSSELL
BULLARD
AVE
FAIRFAX
PWD-S13
T 13 S
STUDY AREAS
SOIL SAMPLING SITES
WATER SAMPLING SITES
PWD-3
SHIELDS AVE
PANOCHE DRAINAGE DISTRICT

Figure 6. Map of the 17,800 ha Panoche Drainage District in the San Joaquin Valley.

in Fig. 6) for reuse by the Grasslands Water District, an irrigated pasture-waterfowl habitat entity. The major crops grown in the PDD are tomato, cotton, and winter barley. The first two crops mentioned are furrow-irrigated. Unlike GCID, the irrigation season in PDD encompassed the calendar year, January through December, 1975.

Table 1 contains the input data and coefficients for PDD. In addiion to those sources of information and data listed for GCID, other data was obtained from an ongoing investigation (Tanji et al., 1976) in PDD. Stored soil water was not considered in the calculations. The mean annual precipitation in this area is about 0.15 m/yr.

Table 4 contains the results of application of this model to PDD. The model predicted flow of surface irrigation return flows to within +17% of monitored value. However, the TDS and salt load were greatly under predicted by using only $M_{sp}-M_{sd}$ in Fig. 4. It is concluded that the presence of native soil gypsum (Table 5) contributed substantially to the dissolved salt load. When it was assumed that the solubility of gypsum in the soil solution is 25 meq/liter, or 21.49 tonnes/ha-m, the calculated results for TDS and the mass of salts in the surface irrigation return flows were -7% and +9%, respectively, of measured values. A further verification of model outputs is the agreement between the calculated 7,146 mg/liter TDS of the soil solution (C'_{sw}) with the measured 6,710-8,900 mg/liter of TDS of tile drainage effluents from the 678 ha tile-drained farm (Fig. 6).

It appears that this steady-state conceptual model has practical utility. How well this model compares with more finely-tuned dynamic models is not known. Although the state-of-the-art of computer modeling has been advanced significantly, the evaluation of soil-salt interactions and predictions on mass emission of salts is usually less than desirable (Biggar and Tanji, 1976).

The final step taken with this model was to project flow, TDS, and salt load in PDD assuming that salt control practices resulted in a hypothetical 20% reduction in diverted water. Table 6 gives the probable effects, where TDS is increased by 6%, return flow decreased by 13%, and salt load decreased by 22%. Due to the presence of gypsum in the soil, TDS is not significantly affected. If gypsum was absent, the percent increase in TDS would be much greater.

Other computed results are given in Table 6, and these may be compared to not only the 1975 PDD study period but also to GCID, Table 3.

Table 4. Results of Model Applied to the Panoche Drainage District for the Calendar Year 1975.

	Measured		Calculated	
Parameter	Measured	No Gypsum	With Gypsum	Difference
Surface Irrigation Return Flow, ha-m	5,585	6,552	—	+17.3%
TDS of Return Flow, mg/ℓ	1,955	458	1,818	-7.0%
Salt Mass in Return Flow, tonnes	109,267	30,027	119,191	+9.1%

Table 5. Soil Data from Panoche Water District *

Depth (m)	EC_e (mmhos/cm)	Estimated Soluble Salts (tonnes/ha-m soil)	Gypsum (tonnes/ha-m soil)	Boron (mg/ℓ)
0.0 -0.15	1.60	7.95	2.86	0.99
0.15-0.3	1.51	7.80	2.79	1.15
0.3 -0.45	1.73	9.79	3.24	1.48
0.45-0.6	2.05	11.11	4.00	2.05
0.6 -0.9	2.80	16.06	4.90	2.80
0.9 -1.2	3.61	20.96	28.34	3.53
1.2 -1.5	3.96	23.22	19.60	3.57
1.5 -1.8	4.17	24.35	38.37	3.50
1.8 -2.1	3.78	22.81	37.46	3.16
2.1 -2.4	4.04	30.91	150.01	3.27
2.4 -2.7	3.64	26.16	107.64	3.83
2.7 -3.0	1.02	4.45	3.02	1.90

* Average of 13 sampling sites to perched water table.

Table 6. Partial Summary of 1975 and Hypothetical Assumed Level of Achieving Salt Control in Panoche Drainage District

Parameter	1975	Assumed Level	% Difference
Diverted Irrigation Water, ha-m/ha	1.02	0.81	-20
Irrigation Application Efficiency	0.75	0.75	---
Irrigation Efficiency	0.45	0.56	---
Leaching Fraction	0.36	0.20	---
Leaching Beyond Root Zone, ha-m/ha	0.28	0.13	-54
Deep Percolation, ha-m/ha	0.20	0.09	-55
Subsurface Drainage, ha-m/ha	0.08	0.04	-50
Irrigation Runoff, ha-m/ha	0.26	0.20	-23
Precipitation Runoff, ha-m/ha	0.03	0.03	---
Surface Irrigation Return Flow, ha-m/ha	0.37	0.27	-27
TDS of Supply Water	234	234	---
ET Concentration Factor of Soil Water	2.78	4.90	---
TDS of Soil Water after ET, mg/ℓ	639	1,120	+75
Salt Pickup-Salt Deposition, tonnes/ha	1.52	0.79	-54
Gypsum Contribution, tonnes/ha	16.76	13.47	---
Final TDS of Soil Water, mg/ℓ	7,146	12,196	+71
TDS of Surface Irrigation Return Flow, mg/ℓ	1,818	1,921	+6
Surface Irrigation Return Flow, ha-m	5,552	4,835	-13
Mass of Salts in Surface Return Flow, tonnes	119,191	92,932	-22

ACKNOWLEDGMENT

This investigation was supported in part by EPA Grant No. R 803603-02, Experiment Station Project No. CA-D*-WSE-3098-H, and University of California Water Resources Center Project No. W-497. A preliminary version of this model was prepared for and submitted to the Staff of the National Commission on Water Quality as part of the contributions from the University of California Committee of Consultants on irrigated agriculture.

LITERATURE CITED

Ayers, R. and R. Coppock. 1974. Salt management: California's most complex water quality problem. Univ. of Calif., Div. of Agr. Sci., Environmental Concerns, 19 pp.

Biggar, J. W. and K. K. Tanji. 1976. Soil-salt interactions in relation to salt control. Trans. Amer. Soc. Agr. Eng. (in press).

California Department of Water Resources. 1967. Vegetative water use. Bull. No. 113-2, 82 pp.

California Department of Water Resources. 1975. Vegetative water use, 1974. Bull. No. 113-3, 104 pp.

Federal Register. 1972. National pollutant discharge elimination system. Environmental Protection Agency. Fed. Reg. 37 (234): 25898-25906, December 5.

Glenn-Colusa Irrigation District. 1971. Water measurement program for 1970. 17 pp. + 28 Tables + 29 Figures and Map.

Glenn-Colusa Irrigation District. 1974. Water measurement program for 1973. 4 pp. + 31 Tables + 26 figures and Maps.

Hornsby, A. G. 1973. Prediction modeling for salinity control in irrigation return flows. U. S. Environmental Protection Agency, Environmental Protection Technical Series, EPA-R2-73-168, 55 pp.

Langelier, W. F. 1936. The analytical control of anticorrosion water treatment. J. Amer. Water Works Assoc., 28:1500-1521.

Low, W. H., K. K. Tanji and A. F. Quek. 1974. Return flow water quality appraisal, Glenn-Colusa Irrigation District, calendar year 1973. I: Water balance, salinity, and suspended matter. Univ. of Calif., Dept of Water Sci. and Eng. Paper 4007, 23 pp.

Rhoades, J. D., R. D. Ingvalson, J. M. Tucker, and M. Clark. 1973. Salts in irrigation drainage waters: I. Effects of irrigation water composition, leaching fraction, and time of year on the salt compositions of irrigation drainage waters. Soil Sci. Soc. Amer. Proc. 37:770-774.

Tanji, K. K., J. W. Biggar, G. L. Horner, R. J. Miller, W. O. Pruitt et al. 1976. 1975-76 Annual Report to the U. S. Environmental Protection Agency on EPA Grant No. R 803603-01-1, Irrigation tail-water management. Univ. of Calif., Dept of Land, Air and Water Resources, Water Sci. and Eng. Paper 4011, 200 pp.

van Schilfgaarde, J., L. Bernstein, J. D. Rhoades and S. L. Rawlins. 1974. Irrigation management for salt control. J. Irrig. and Drainage Div., ASCE 100(IR3):321-338.

APPENDIX

HYDROLOGIC SUBMODEL

Hydrologic Inputs and Outputs

(1) $Q_i = Q_{diw} + Q_p + Q_{ssw}$

(2) $Q_o = Q_{iwro} + Q_{pro} + Q_{et} + Q_{dp} + Q_{sdw}$

Diverted Irrigation Water

(3) $Q_{diw} = Q_{eaiw} + Q_{iwro}$

(4) $Q_{eaiw} = Q_{diw} (E_{iae})$

(5) $Q_{iwro} = Q_{diw} (1-E_{iae})$

Precipitation

(6) $Q_p = Q_{pro} + Q_{etp} + Q_{ep}$

(7) $Q_{pro} = a\ Q_p$

(8) $Q_{etp} = b\ Q_p$

(9) $Q_{ep} = c\ Q_p$

Water Inflow to Root Zone

(10) $Q_{sw} = Q_{eaiw} + Q_{ep} + Q_{ssw}$

(11) $Q_{ssw} = d\ (D_{whc})(D_r)(A)$

Water Outflow from Root Zone

(12) $Q_{sw} = Q_{et} + Q_{dp} + Q_{sdw}$

(13) $Q_{et} = e\ (D_{pet})(A)$

(14) $Q_{dp} = f\ (Q_{sw} - Q_{et})$

(15) $Q_{sdw} = (1 - f)(Q_{sw} - Q_{et})$

Surface Return Flow

(16) $Q_{sirf} = Q_{iwro} + Q_{pro} + Q_{sdw}$

Irrigation Efficiency and Leaching Fraction

(17) $E_{ie} = [Q_{sw} - (Q_{sirf} + Q_{dp})]/Q_{sw}$

(18) $LF = (Q_{sw} - Q_{et})/Q_{sw}$

SALINITY SUBMODEL

Salt Inputs and Outputs

(19) $M_i = M_{diw} + M_p + M_{ssw} + M_{sp}$

(20) $M_o = M_{iwro} + M_{pro} + M_{dp} + M_{sdw} + M_{sd}$

Diverted Irrigation Water

(21) $M_{diw} = (C_{iw})(Q_{diw})(SMCF)$

(22) $C_{iwro} = C_{iw} + C_{iwrosp}$

(23) $M_{iwro} = (C_{iwro})(Q_{diw})(SMCF)$

Precipitation

(24) $M_p = (C_p)(Q_p)(SMCF)$

(25) $C_{pro} = C_p + C_{prosp}$

(26) $M_{pro} = (C_{pro})(Q_{pro})(SMCF)$

ET Concentration Factor

(27) $ETCF = Q_{sw}/(Q_{sw} - Q_{et})$

Soil Water After ET

(28) $C_{sweaiw} = C_{iw}\ (ETCF)$

(29) $C_{swep} = C_p\ (ETCF)$

(30) $C_{ssw} = C_p(ETCF)$ or $C_{iw}\ (ETCF)$

(31) $Q_{sweaiw} = (Q_{eaiw}/Q_{sw})(Q_{sw} - Q_{et})$

(32) $Q_{swep} = (Q_{ep}/Q_{sw})(Q_{sw} - Q_{et})$

(33) $Q_{sssw} = (Q_{ssw}/Q_{sw})(Q_{sw} - Q_{et})$

(34) $C_{sw} = [(C_{sweaiw})(Q_{sweaiw}) + (C_{swep})(Q_{swep}) + (C_{ssw})(Q_{sssw})]/(Q_{sw} - Q_{et})$

Salt Pickup-Salt Deposition

(35) $(M_{sp} - M_{sd})$, obtained from Figure 5

Soil Water After ET and Salt Pickup-Salt Deposition

(36) $M_{sw} = (C_{sw})(Q_{sw} - Q_{et})(SMCF) + (M_{sp} - M_{sd}) + (G_{sp})$

(37) $C'_{sw} = M_{sw}/[(Q_{sw} - Q_{et})SMCF]$

Deep Percolation and Subsurface Drainage

(38) $C'_{sw} = C_{dp} = C_{sdw}$

(39) $M_{dp} = (C_{dp})(Q_{dp})(SMCF)$

(40) $M_{sdw} = (C_{sdw})(Q_{sdw})(SMCF)$

Surface Irrigation Return Flow

(41) $C_{sirf} = [(C_{iwro})(Q_{iwro}) + (C_{pro})(Q_{pro}) + (C_{sdw})(Q_{sdw})]/(Q_{iwro} + Q_{pro} + Q_{sdw})$

(42) $M_{sirf} = (C_{sirf})(Q_{sirf})(SMCF)$

DEFINITIONS OF SYMBOLS

Q_i = Hydrologic Input

Q_o = Hydrologic Output

Q_{diw} = Diverted Irrigation Water

E_{iae} = Irrigation Application Efficiency

Q_{eaiw} = Effective Applied Irrigation Water

Q_{iwro} = Irrigation Water Runoff

Q_p = Precipitation

Q_{pro} = Precipitation Runoff

Q_{etp} = ET of Precipitation

Q_{ep} = Effective Precipitation

a = Precipitation Runoff Coefficient

b = Precipitation ET Coefficient

c = Effective Precipitation Coefficient

Q_{sw} = Soil Water

Q_{ssw} = Stored Soil Water

d = Stored Soil Water Coefficient

D_{whc} = Unit Water Holding Capacity

D_r = Rooting Depth

A = Land Area

Q_{et} = Evapotranspiration

e = ET Coefficient

Q_{pet} = Potential Evapotranspiration

Q_{dp} = Deep Percolation

f = Deep Percolation Coefficient

Q_{sdw} = Subsurface Drainage Water

Q_{sirf} = Surface Irrigation Return Flow

E_{ie} = Irrigation Efficiency

LF = Leaching Fraction

M_i = Salt Input

M_o = Salt Output

C_{iw} = TDS of Diverted Irrigation Water

M_{diw} = Salt Mass in Diverted Irrigation Water

SMCF = Salt Mass Conversion Factor

C_{iwrosp} = Salt Pickup by Tailwater

C_{iwro} = TDS of Tailwater

M_{iwro} = Salt Mass in Tailwater

C_p = TDS of Precipitation

M_p = Salt Mass in Precipitation

C_{prosp} = Salt Pickup by Precipitation Runoff

C_{pro} = TDS of Precipitation Runoff

M_{pro} = Salt Mass in Precipitation Runoff

ETCF = ET Concentration Factor

C_{sweaiw} = TDS of Q_{eaiw} after ET

C_{swep} = TDS of Q_{ep} after ET

C_{ssw} = TDS of Q_{ssw} after ET

Q_{sweaiw} = Q_{eaiw} after ET

Q_{swep} = Q_{ep} after ET

Q_{sssw} = Q_{ssw} after ET

C_{sw} = TDS of Soil Water after ET

$(M_{sp} - M_{sd})$ = Salt Pickup-Salt Deposition

G_{sp} = Dissolved Gypsum

C'_{sw} = TDS of Soil Water after ET, $(M_{sp} - M_{sd})$, and G_{sp}

M_{sw} = Salt Mass in Soil Water

C_{dp}, C_{sdw} = TDS of Deep Percolation and Subsurface Drainage

M_{dp}, M_{sdw} = Salt Mass in Deep Percolation and Subsurface Drainage

C_{sirf} = TDS of Surface Return Flow

M_{sirf} = Salt Mass in Surface Return Flow

ESTIMATION OF CROP WATER USE IN THE PANOCHE WATER DISTRICT

W. O. Pruitt

Department of Land, Air and Water Resources
Water Science and Engineering Section
University of California, Davis

The use of water loss data from Class A, U.S. Weather Service pans to estimate crop water use has been a well recognized procedure for years. Fortunately in California many studies have been conducted of the relationship between evaporation and crop water use.[1,2,3,4] Two recent International publications outline refined procedures for estimating crop water use from pan data which take into account local pan environment (effect of surrounding crops and general levels of wind and relative humidity.[5,6]

---

[1] Nixon, P. R. and G. Paul Lawless. Agricultural watershed and associated basins evapotranspiration losses in Central and Southern California. Annual Research Report-1966. USDA (ARS), Lompoc, Calif. 1966.

[2] Pruitt, W. O. Empirical method of estimating evapotranspiration using primarily evaporation pans. Proc. Conf. on Evapotranspiration. Am. Soc. Agr. Eng., Chicago. Dec. 1966. pp. 57-61.

[3] Pruitt, W. O., F. J. Lourence and S. von Oettingen. Water use by crops as affected by climate and plant factors. California Agriculture. Oct. 1972.

[4] California Dept. of Water Resources. Vegetative water use in California. DWR Bull. No. 113-3. 1975.

[5] Jensen, M. E. (ed.). Consumptive use of water and irrigation water requirements. Tech. Committee on Irrig. Water Requirements, Irrig. and Drainage Div., Am. Soc. Civ. Eng. 1974.

[6] Doorenbos, J. and W. O. Pruitt. Crop water requirements. Irrig. and Drainage Paper No. 24, FAO, Rome. 1975, 1977.

Since some aspects of the present study could be enhanced by a knowledge of the evapotranspiration (ET) component of the water balance, an evaporation pan was established in an irrigated pasture near the Panoche Water District Office in late June of 1975. Daily readings, and most of the maintenance of the evporation station were handled by District personnel. At times the float mechanism between the pan and the supply tank failed with resultant loss of records. At times the grass in the enclosure was allowed to grow too high before clipping, resulting in reduced evaporation. For such periods a pan operated by the California Department of Water Resources located in an irrigated pasture at Wasco, some 130 miles to the SE, was used to provide estimates.[7] To provide for two complete years of data the Wasco pan data were used directly for the February-June 15 period.

Tables 1 and 2 provide bimonthly evaporation data for 1975 and 1976. In addition, bimonthly estimates of ET for most of the important crops in the Panoche District are included. These crop ET data are based on a recent careful analysis by the Interagency Agricultural Information Task Force of crop coefficient curves from the many studies of SDWR, the University of California and the USDA (ARS). Data for at least two planting dates are provided for all crops except pasture, alfalfa and cotton. It should be pointed out that alfalfa for two weeks or so before cutting uses some 10-20% more water than a typical pasture but less than 1/2 that of grass for a week following cuttings. These effects have been smoothed out in Table 1 and 2.

---

[7] It should be noted that earlier estensive SDWR studies had shown the evaporation potential throughout the entire Central Valley of California showed little variation on a monthly basis for all pans located within a large irrigated pasture site. Hence, the extrapolation from a site 130 miles away is considered reasonable.

Also the grain and sugar beet totals for the situations with planting in one year and harvest the following year are based on data within the particular calendar year in order to obtain two full years of estimates.

In Table 3 the upper portion contains a computation of total acre feet for each of the crops where estimated ET was obtained from Tables 1 and 2. Estimates were also calculated for additional crops but based on our best estimates of total seasonal ET. It is noted that the average estimated ET for the entire cropped acreage averaged around 2.35 AF/A for both years. This does not include nongrowing season ET for the project crops. Information in this table can be used in an overall analysis of water and salt balance for this San Joaquin Valley site.

Table 1. 1975 Class A pan evaporation (irrigated pasture environment) near the Panoche Water District headquarters[1/] along with crop water use (ET) estimates for a number of crops grown on the project in acre inches/acre.

Binonthly period		E_{pan}	Pasture	Alfalfa	Tomatoes		Field Corn		Small Grain		Cotton	Melons		Sugar Beets	
					3/1 plant	4/1 plant	4/15	5/15	11/1	1/1	4/15	3/15	4/15	3/15	6/15
Jan.	1	.50	.36	.38					.31	.11					.42
	2	1.10	.80	.84					.88	.29					.92
Feb.	1	1.05	.78	.80					.97	.38					.68
	2	1.35	1.01	1.03					1.31	.73					1.13
Mar.	1	1.85	1.41	1.41	.37				1.79	1.44					1.55
	2	2.80	2.16	2.13	.56				2.63	2.52		.39		.34	
Apr.	1	2.60	2.03	1.98	.52	.52			2.29	2.47		.47		.44	
	2	2.75	2.17	2.11	.66	.55	.41		1.79	2.67	.36	.77	.39	.71	
May	1	3.80	2.96	2.89	1.41	.91	.72		1.33	3.61	.61	2.13	.76	1.56	
	2	4.30	3.35	3.27	2.62	1.59	1.46	.65		3.01	.99	3.70	1.38	3.27	
Jun.	1	5.10	3.98	3.88	4.39	3.11	2.86	1.12		2.55	2.35	4.39	3.42	4.54	
	2	5.30	4.13	4.03	4.93	4.56	4.77	1.96		1.33	3.87	4.56	4.56	4.82	.95
Jul.	1	5.40	4.21	4.10	4.91	5.02	5.08	4.27			5.18	4.05	4.64	4.97	1.35
	2	5.15	4.02	3.91	4.17	4.69	4.84	4.79			5.15	.82	3.86	4.69	2.93
Aug.	1	4.45	3.47	3.38	3.03	3.61	3.92	4.18			4.45		.71	4.05	3.96
	2	4.40	3.43	3.34		2.99	3.12	4.00			4.27			3.92	4.05
Sep.	1	3.85	3.00	2.93			1.77	2.97			3.21			3.19	3.54
	2	3.30	2.54	2.51				1.85			2.08				3.07
Oct.	1	3.00	2.28	2.28							1.26				2.79
	2	2.05	1.54	1.56											1.89
Nov.	1	1.25	.93	.95					.21						1.13
	2	.90	.66	.68					.20						.79
Dec.	1	.60	.43	.46					.17						.50
	2	.80	.56	.61					.34						.67
Total			52.2	51.5	27.6	27.5	28.9	25.8	14.2	21.1	33.8	21.3	19.7	32.5	31.4

[1/] Data for Jan. 1 through Jun. 20 and Aug. 20 through Sep. 30 are based on SDWR pan at Wasco. Occasional missing or suspect daily data during the rest of the year are also based largely on Wasco data.

Table 2. 1976 Class A pan evaporation near the Panoche Irrigation District headquarters[1] along with estimates of crop water use in acre inches/acre.

Bimonthly period		E_{pan}	Pasture	Alfalfa	Dry Beans		Tomatoes		Field Corn		Small Grains		Cotton	Melons		Sugar Beets	
					5/1 plant	6/15 plant	3/1	4/1	4/15	5/15	11/1	1/1	4/15	3/15	4/15	3/15	6/15
Jan.	1	.50	.36	.38							.31	.11					.42
	2	.85	.62	.64							.68	.22					.71
Feb.	1	1.20	.89	.91							1.10	.43					1.01
	2	.95	.71	.72							.92	.51					.80
Mar.	1	1.65	1.25	1.25			.33				1.60	1.29					1.39
	2	2.70	2.08	2.05			.54				2.54	2.43		.38		.32	
Apr.	1	2.40	1.87	1.82			.48	.48			2.11	2.23		.43		.41	
	2	3.10	2.42	2.36			.74	.62	.47		2.01	3.01	.40	.87	.43	.81	
May	1	4.05	3.16	3.08	.45		1.50	.97	.77		1.42	3.85	.65	2.27	.81	1.66	
	2	4.25	3.31	3.23	1.32		2.59	1.57	1.45	.64		2.97	.98	3.65	1.36	3.23	
Jun.	1	4.40	3.43	3.34	3.78		3.78	2.68	2.46	.97		2.20	2.02	3.78	2.95	3.92	
	2	5.35	4.17	4.07	4.76	.59	4.98	4.60	4.81	1.98		1.34	3.91	4.60	4.60	4.87	.96
Jul.	1	5.40	4.21	4.10	4.81	1.67	4.91	5.02	5.08	4.27			5.18	4.05	4.64	4.97	1.35
	2	4.95	3.86	3.76	3.91	4.26	4.01	4.50	4.65	4.60			4.95	.79	3.71	4.49	2.81
Aug.	1	4.60	3.59	3.50	1.88	4.09	3.13	3.73	4.05	4.32			4.60		.74	4.19	4.09
	2	4.35	3.39	3.31		3.87		2.96	3.09	3.96			4.22			3.87	4.00
Sep.	1	3.20	2.50	2.43		2.53			1.47	2.46			2.69			2.66	2.94
	2	2.80	2.16	2.13		1.15				1.57			1.76				2.60
Oct.	1	2.30	1.75	1.75									.97				2.14
	2	1.80	1.35	1.37													1.66
Nov.	1	1.20	.89	.91							.21						1.08
	2	.40	.29	.30							.20						.35
Dec.	1	.75	.53	.57							.17						.63
	2	.60	.42	.46							.34						.50
Total			49.2	48.4	20.9	18.2	27.0	27,1	28.3	24.8	13.6	20.6	32.3	20.8	19.2	35.4	29.4

[1] Data for 4/20-6/10 and for 9/1-11/10 are based on SDWR pan at Wasco.

Table 3. Crop acreage and estimated crop water use (ET) for Panoche Water District, 1975 and 1976.

Crop		1975 Crop ET				1976 Crop ET		
	Acres	In.	Ft.	Ac. Ft.	Acres	In.	Ft.	Ac. Ft.
Pasture	1,236	52.2	4.35	5,377	157	49.2	4.10	644
Alfalfa	472	51.5	4.29	2,025	724	48.4	4.03	2,918
Beans	-0-	20.2	1.68	-	700	19.5	1.63	1,141
Tomatoes	7,506	27.6	2.30	17,264	4,302	27.1	2.26	9,723
Corn	750	27.4	2.28	1,700	676	26.5	2.21	1,494
Small Grains	4,856	17.6	1.47	7,138	4,494	17.1	1.43	6,426
Cotton	11,004	33.8	2.82	31,031	14,477	32.3	2.69	38,943
Melons	4,103	20.5	1.71	7,016	2,358	19.1	1.59	3,749
Sugar Beets	1,069	32.0	2.67	2,854	737	32.4	2.70	1,990
	30,996			74,405 A.F.	28,625			67,028 A.F
Other Crops:								
Alfalfa Seed	886	40	3.3	2,924	388	39	3.2	1,242
Lettuce	862	14	1.2	1,034	544	13	1.1	598
Rice	-	-		-	140	39	3.2	448
Almonds	118	37	3.1	366	90	36	3.0	270
Carrot Seed	-	-		-	206	36	2.2	453
Garlic	344	30	2.5	860	118	29	2.4	283
Safflower	1,617	20	1.7	2,749	467	19	1.6	747
Prunes	127	37	3.1	394	-	-		-
Veg. Seed	120	20	1.7	204	-	-		-
Peppers	-				101	30	2.5	
	4,074			8,531 A.F.	2,054			4,041 A.F
Total	35,070			82,936 A.F.	30,679			71,069 A.F
				= 2.36 A.F./A				= 2.32 A.F./A

CHAPTER V. SAN JOAQUIN VALLEY FIELD STUDIES

The selection of field study sites was closely coordinated with the California Regional Water Quality Control Board-Central Valley Region, the Mendota-Crows Landing Return Flow Group, and the Sacramento Valley Water Quality Committee. The latter two water user organizations are California's first two and largest National Pollutant Discharge Elimination System (NPDES) permittees for discharge of irrigation return flows.

A. Mendota-Crows Landing Return Flow Group

The Mendota-Crows Landing Return Flow Group contains 400,000 acres of diversified land use including highly productive farm land, located on the west side of the San Joaquin Valley in Fresno, Merced, and Stanislaus Counties. The area is bounded on the west by Diablo Mountain Range, the Highway Interstate 5, the California Aqueduct and on the east by San Joaquin River, and extends from the Mendota Pool near the town of Mendota in Fresno County and beyond Orestimba Creek near the town of Crows Landing in Stanislaus County as shown in Fig. V-1. The group consists of 17 entities representing water and drainage districts, canal companies, wildlife and grasslands areas, and individual landowners. On July 25, 1975, this return flow group received an NPDES permit to discharge irrigation return flows into the middle reaches of San Joaquin River. This initial permit expires on July 25, 1977.

Two distinct cultural patterns are represented within this study area. They are the areas that are extensively cropped, producing surface and subsurface return flows; and the native pastures and wildlife areas which utilize the return flows produced on the irrigated croplands. As return flows move downslope, they are diverted for reuse a number of times. Quantities and qualities change rapidly reflecting local differences in soil

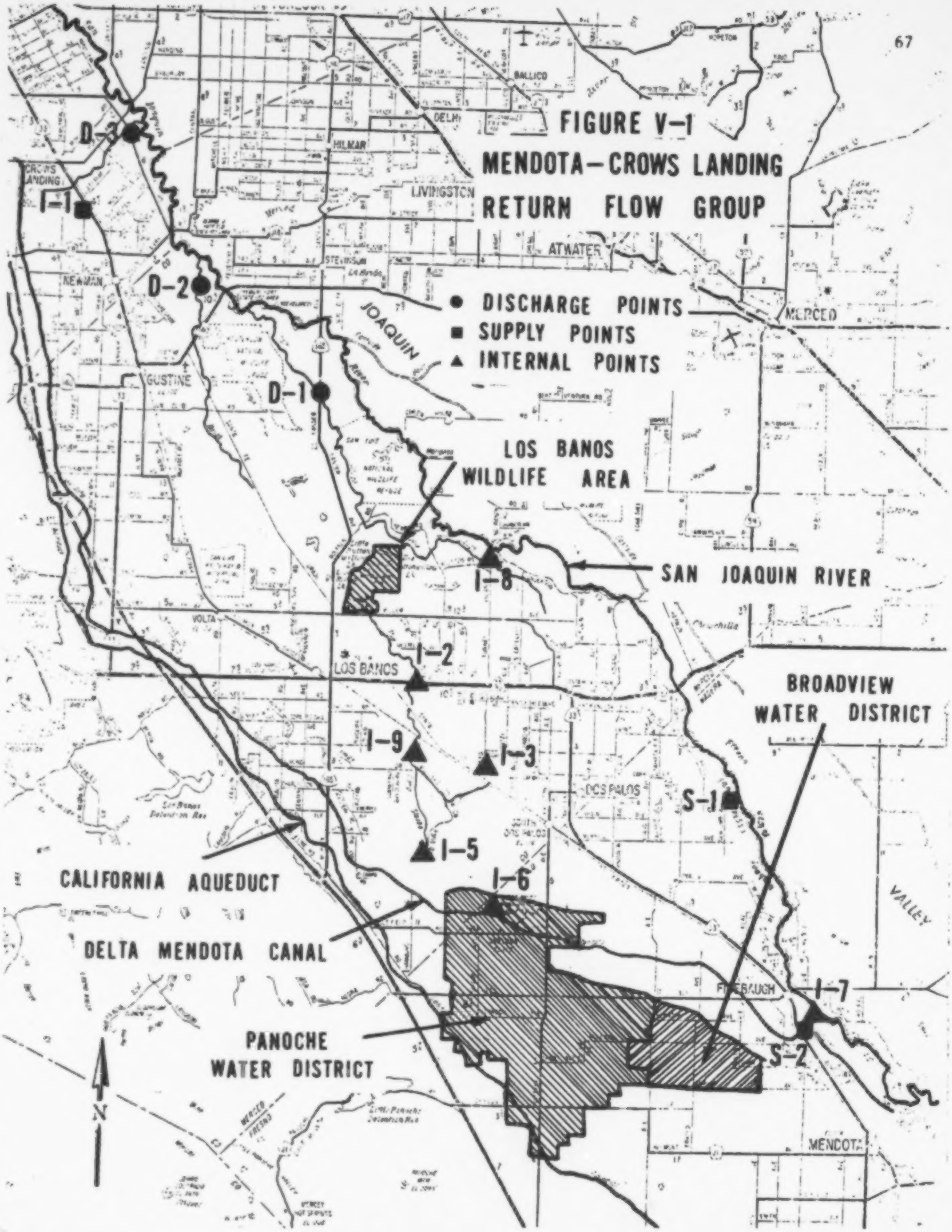


FIGURE V-1
MENDOTA-CROWS LANDING
RETURN FLOW GROUP

● DISCHARGE POINTS
■ SUPPLY POINTS
▲ INTERNAL POINTS

D-3
CROWS LANDING
I-1
NEWMAN
D-2
GUSTINE
D-1
HILMAR
DELHI
BALLICO
LIVINGSTON
ATWATER
STEVINSON
MERCED
JOAQUIN
LOS BANOS WILDLIFE AREA
I-8
SAN JOAQUIN RIVER
VOLTA
I-2
LOS BANOS
BROADVIEW WATER DISTRICT
I-9
I-3
DOS PALOS
S-1
I-5
CALIFORNIA AQUEDUCT
I-6
VALLEY
DELTA MENDOTA CANAL
FIREBAUGH
I-7
S-2
PANOCHE WATER DISTRICT
MENDOTA
N

properties, cropping patterns, cultural practices, and the amount of reuse made of the return flows prior to their being discharged into the middle reaches of the San Joaquin River. The co-mingled surface and subsurface return flows are, prior to final discharge, collected and reused during the summer and fall months on the 133,952 acres devoted to wildlife habitats and native pastures. There are approximately 19,000 acres devoted to public use and 170 waterfowl clubs represented in this area. This reuse of irrigation return flows is one of the dominating factors affecting the quantity and quality eventually discharged in the San Joaquin River.

The major source of supply water is imported via the Delta-Mendota Canal, as part of the U.S. Bureau of Reclamation's Central Valley Water Project. Water is delivered initially to the Mendota Pool and then distributed in a northeasterly direction by several canals. Other minor sources of irrigation water are pumped groundwaters, the California Aqueduct, and recaptured return flows. The general direction of drainage is eastwards from the alluvial fans in the west towards the basin rim, and northeasterly on the valley floor and lower alluvial fans.

This return flow group has a permit to discharge irrigation return flows from Salt Slough (D-1), Mud Slough North (D-2), and Orestimba Creek (D-3). The Group is required to monitor and report water flows (Q), electrical conductivity (EC), and suspended solids (SS) on a weekly frequency during the irrigation season. The Group also monitors and reports Q, EC, and SS of its supply waters at the head of Arroyo Canal in the San Joaquin River (S-1) and in the Delta-Mendota Canal at the Firebaugh Wasteway (S-2) on a monthly basis.

Cooperative arrangements have been made with the NPDES permittee to obtain water samples for quality analyses and flow measurements. In addition to EC and SS, our project is also determining total dissolved solids (TDS), turbidity in Jackson Turbidity Units (JTU), boron, and pH. More detailed analyses are carried out several times a year for the dissolved mineral salt constituents, various nitrogen species, biochemical oxygen demand (BOD), dissolved oxygen (DO), etc.

In addition to the NPDES monitoring stations, this project has eight internal stations (Fig. V-1) in the drainage and/or supply network, upstream from the NPDES discharge stations. Flow is being measured/estimated wherever possible, and quality data similar to that obtained for the NPDES stations are being collected on a monthly basis.

The above represents the water quality survey for this return flow group. Other spatial evaluations are also being conducted; namely, at the district and on-farm levels. Individual entities within the return flow group being studied are the Broadview and Panoche Water Districts, and the Los Banos Wildlife Area (Fig. V-1). On-farm studies being conducted in the Panoche Water District consist of a 170-ac field equipped with a tailwater recovery system and cropped to furrow-irrigated lettuce and melons in the 1976 irrigation season; and a 1,700-ac tile-drained field in which tile spacing is progressively being decreased from 600 to 300 ft and which utilizes a blend of freshwater, surface runoff, and tile drainage effluent for irrigation.

Water quality and flow data for this return flow group are tabulated in Appendix Tables 1-14. It should be mentioned that monitoring was done year-round. The irrigation season in this area may commence as early as January or as late as April, and may terminate as early as October or extend into December, depending upon winter rainfall and the need to renovate the supply distribution system. But for this report, the "irrigation season" will encompass the period April through October.

Table V-1 contains for the April through October, 1976, irrigation season a list and description of the NPDES and EPA monitoring stations, along with seasonal Q in ac-ft and the seasonal average of selected quality parameters. The NPDES supply and discharge stations presumably include the major supply and discharge points, but they do not appear to represent the total supply nor the total discharge. Thus, it is not possible to fully appraise the mass inflow and mass outflow of salinity, suspended matter, or other parameters in this return flow group. Similar sets of data are presented in Tables V-2 and V-3 for the "nonirrigation seasons" (i.e., November through March) for 1975-76 and 1976-77, respectively. This second-year annual report covers the whole period of November, 1975, to March, 1977.

Table V-1 points out that the quality of discharge waters from the NPDES stations is different. Substantial increases in salinity (EC, TDS) are noted for D-1 and D-2, over that of S-1 and S-2. These increases in salinity are attributed to the concentrating effect of evapotranspiration; i.e., pure water (more or less) is lost to the atmosphere while salts present in the applied irrigation water remain in the soil. In addition salt pickup can occur from the chemical weathering of soils, some of which are salt-affected in this area. Station D-3 is different since its flows consist of operational spills, together with irrigation return flows from croplands.

Furthermore, the suspended matter (turbidity and SS) is substantially higher for D-3 than other NPDES stations. The large suspended load in Orestimba Creek is probably due to a steeper gradient than in Salt Slough or in Mud Slough North, resulting in a greater current velocity. This keeps sediments in suspension and/or picks up silt and clay laid down in the creek bed during winter runoffs from the Coast Range watershed. Other sources of sediments are tailwater runoffs from row crops. In addition to the slower current velocities in Salt Slough and Mud Slough North, the suspended load

Table V-1: Flow-Weighted Water Quality Parameters for the NPDES and EPA Monitoring Stations in Mendota-Crows Landing Return Flow Group,*

April 1976 Through October 1976 (Irrigation Season)

Station	Description	Quantity (ac-ft)	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
NPDES Supply Stations								
S-1	Arroyo Canal	150,266	548	331	43	91	0.16	8.0
S-2	Delta-Mendota Canal	838,972	474	279	41	78	0.17	8.0
NPDES Discharge Stations								
D-1	Salt Slough	51,802	1,399	808	46	105	0.45	7.9
D-2	Mud Slough North	13,366	1,617	979	51	69	1.16	8.7
D-3	Orestimba Creek	10,182	683	394	212	306	0.29	7.8
EPA Internal Stations								
I-1	CCID Main Canal†	62,785	771	447	77	131	0.48	7.9
I-3	Bennett Drain	1,725	2,621	1,653	32	54	1.07	7.7
I-5	Camp 13 Slough	12,744	3,569	2,526	168	286	3.87	7.9
I-6	Panoche District Drain	19,869	3,058	2,099	208	308	5.09	7.9
I-7	Firebaugh Wasteway†	--	1,632	1,061	50	86	1.28	8.0
I-8	Turner Island Intake†	15,983	843	458	56	127	0.24	7.8
I-9	Mud Slough below Geis Ditch	23,828	3,286	2,280	75	142	5.17	8.0

* If water flows are available, quality parameters are flow-weighted averages; if not available, quality parameters are simply seasonal averages.

† Also supply source.

Table V-2: Flow-Weighted Water Quality Parameters for the NPDES and EPA Monitoring Stations in Mendota-Crows Landing Return Flow Group,*

November 1975 Through March 1976 (Non-Irrigation Season)

Station	Description	Quantity (ac-ft)	EC x 10^6 (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
NPDES Supply Stations							
S-1	Arroyo Canal	25,043	579	346	18	26	0.22
S-2	Delta-Mendota Canal	184,543	806	474	21	35	0.31
NPDES Discharge Stations							
D-1	Salt Slough	30,532	2,294	1,594	22	34	1.40
D-2	Mud Slough North	34,143	2,824	1,888	33	58	2.73
D-3	Orestimba Creek	1,615	992	619	22	30	0.36
EPA Internal Stations							
I-1	CCID Main Canal†	6,727	961	583	26	39	0.45
I-2	Mud Slough South**	--	2,663	1,845	18	27	3.18
I-3	Bennett Drain***	264	2,713	1,816	31	48	2.55
I-5	Camp 13 Slough	4,995	5,105	3,812	42	110	7.13
I-6	Panoche District Drain	12,814	2,167	1,484	127	263	3.23
I-7	Firebaugh Wasteway†	--	1,214	796	31	40	0.66
I-8	Turner Island Intake†	4,224	962	585	36	71	0.18
I-9	Mud Slough below Geis Ditch‡	5,556	3,542	2,069	71	125	4.88

* If water flows are available, quality parameters are flow-weighted averages; if not available, quality parameters are simply seasonal averages.

** November 1975 through February 1976, straight averages. Discontinued in March 1976.

*** The flow is only for the month of March 1976 and quality parameters are straight averages for the season.

† Also supply source.

‡ March 1976 only.

Table V-3: Flow-Weighted Water Quality Parameters for the NPDES and EPA Monitoring Stations in Mendota-Crows Landing Return Flow Group*

November 1976 Through March 1977 (Non-Irrigation Season)

Station	Description	Quantity (ac-ft)	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
NPDES Supply Stations								
S-1	Arroyo Canal	20,815	1,125	631	20	28	0.25	8.1
S-2	Delta-Mendota Canal	135,828	948	533	16	22	0.15	8.1
NPDES Discharge Stations								
D-1	Salt Slough	29,427	2,731	1,708	21	41	1.84	8.2
D-2	Mud Slough North	28,443	2,507	1,205	31	32	1.88	8.4
D-3	Orestimba Creek	1,030	1,468	891	15	19	0.59	8.2
EPA Internal Stations								
I-1	CCID Main Canal†	5,566	1,632	995	30	61	0.83	8.1
I-3	Bennett Drain	234	3,922	2,629	25	36	2.89	8.2
I-5	Camp 13 Slough	4,460	4,119	2,943	68	146	4.38	8.2
I-6	Panoche District Drain	9,688	3,829	2,632	143	291	5.28	8.2
I-7	Firebaugh Wasteway†	--	2,117	1,370	25	34	1.26	8.2
I-8	Turner Island Intake†	2,738	1,318	753	27	48	0.11	8.2
I-9	Mud Slough below Geis Ditch	16,832‡	4,480	2,577	39	51	4.96	8.3

* If water flows are available, quality parameters are flow-weighted averages; if not available, quality parameters are simply straight averages.

† Also supply source. March 1977 only.

‡ Flow November 1976 to February 1977.

is smaller since a significant amount of the suspended load in the irrigation return flow is deposited in grassland and wildlife areas, where reuse takes place.

The boron concentration at D-3 was slightly higher than that of the supply water while it is substantially higher at D-1 and D-2 due to the leaching of boron-affected soils in the area. Soil salinity and soil boron data are presented later, in the district-level assessments.

Internal stations I-1, I-7, and I-8 in the drainage network also provided supply waters for the low-lying croplands, grassland, and wildlife refuges. These waters are approximately two to three times as saline as the fresh supply water found in the Delta-Mendota Canal (S-2). Boron is also higher at I-1 and I-7, as compared to S-2. Suspended matter is extremely high in I-8, as compared to other irrigation return flows. Other more saline-high boron drain waters (I-3, I-5, I-6, and I-9) were discharged into Salt Slough and Mud Slough North or their tributaries, and reused in pastures and wildlife habitats before final discharge into the main drains. Note that the salinity in these drains is about 5.5 to 7.5 times greater than S-2, and boron ranges from 1.1 to 5.2 mg/liter.

Comparing the 1976 vs. the 1975 irrigation seasons (first-year annual report) the quantity and quality at these stations were similar. Hydrologic year 1976 is the first of two consecutive dry-year conditions faced in the Central Valley but since the water used in this area is primarily that which is imported, no significant impacts occurred in the 1976 irrigation season. This is probably not true of the 1977 irrigation season since project water has been cut back to only 25% of normal.

As for the nonirrigation season periods of 1975-76 and 1976-77, no major differences were also noted, but when compared to the 1976 irrigation season, salinity and boron were generally higher while turbidity and suspended solids were generally lower during the nonirrigation season.

For illustrative purposes, Fig. V-2 plots the temporal changes in Q, EC, and SS for supply station S-2 from May, 1975, to March, 1977, and a similar plot is given in Fig. V-3 for the discharge station D-1. The peak flow in S-2 occurred in midsummer (from June through August) for both years. In contrast, the peak flow in D-1 was from mid-August to early September for both years. Some of the contributing factors to the lag time noted between delivery and discharge are drainage of rice fields prior to harvest, travel time through soils and collection as return flows in canals, and the reuse and discharge of waters from the wildlife and grassland areas. In addition high flows in D-1 occurred at other times as in February-March of 1976 and 1977, mostly probably due to the discharge of water from the gun clubs and wildlife areas. The discharge during February-March of 1977 was considerably less than in 1976 because of the water deficiency and the wildlife areas were not drained as in the past.

Monthly measurements of EC of the supply water were low, except for the months of August, 1975, March, 1976, and 1977. It is known that EC varies widely in the Delta-Mendota Canal and that monthly grab samples may not be truly representative as pointed out in the previous annual report (see Appendix Fig. 1). These variations in EC may be attributed to the variations in the outflow from the Sacramento and San Joaquin River systems, and sea water intrusion into the Delta which is partly influenced by tidal movement. The EC of discharge water was consistently higher by about 3- to 4-fold except in October, 1975, when discharge decreased substantially (due to the filling of duck ponds) with a concurrent rise in EC. In December and January of each year, the EC values increased because there was almost no flow into the drains at this time except for precipitation runoff. The supply water

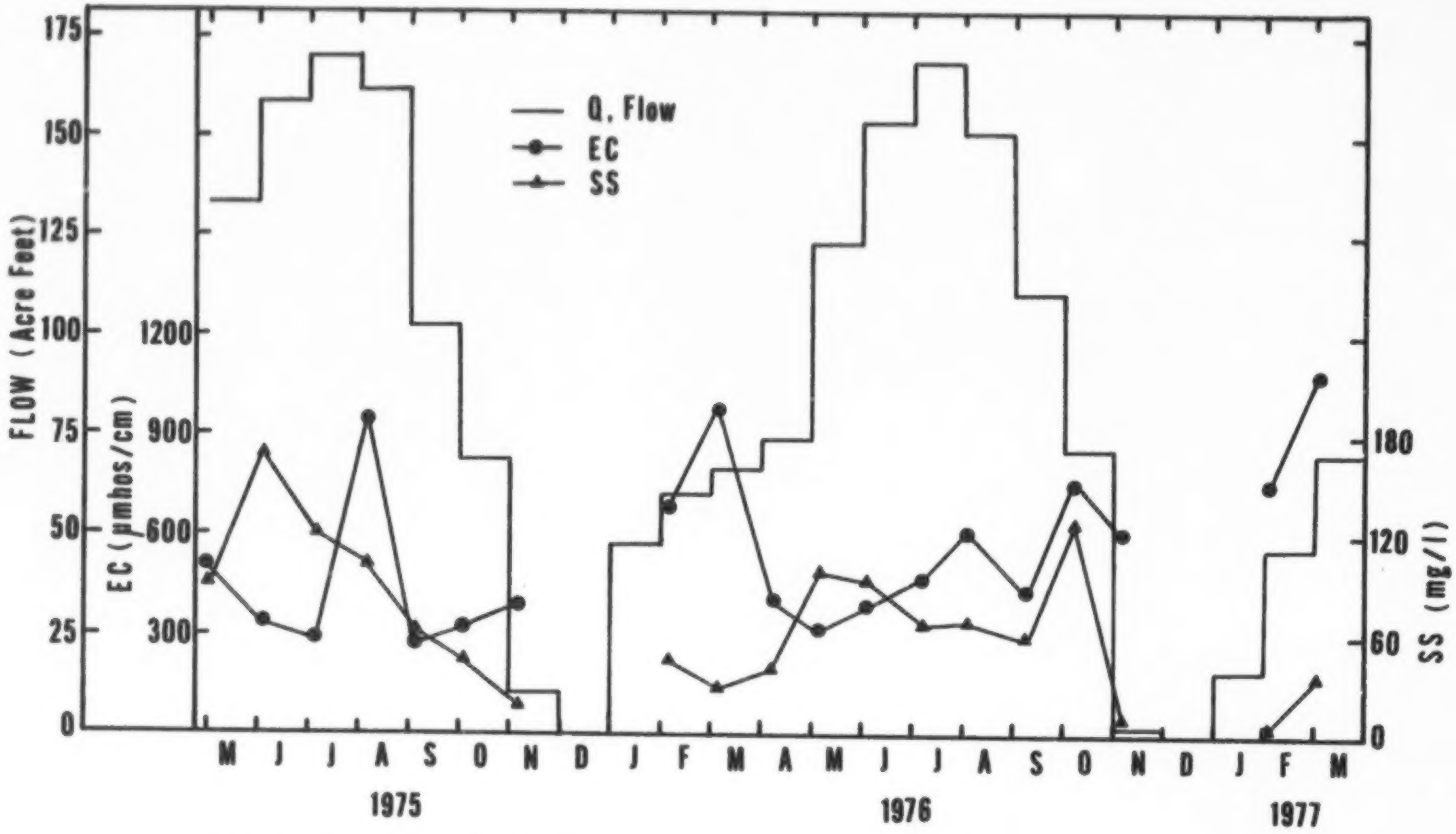


FIG. V—2: FLOW, EC AND SS FOR SUPPLY STATION S—2, MAY 1975 THROUGH MARCH 1977.

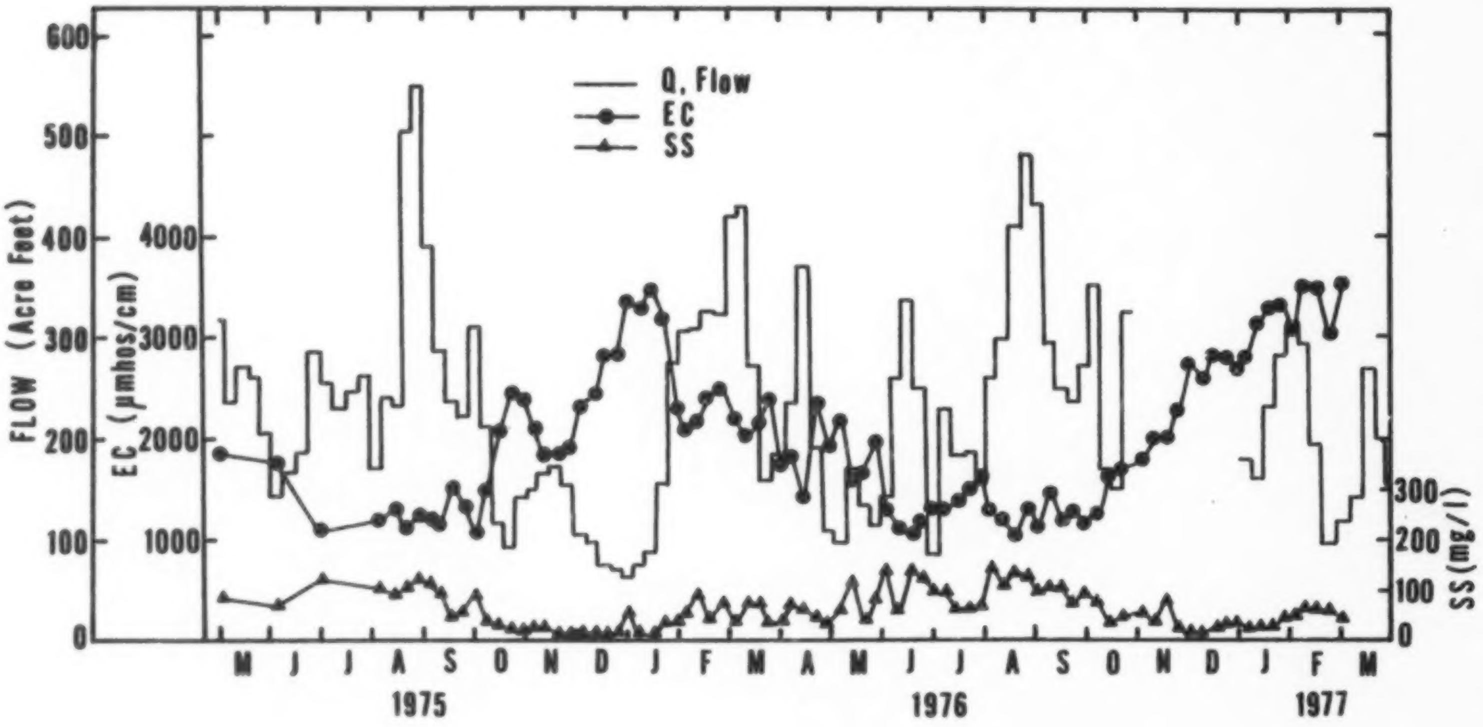


FIG. V–3: FLOW, EC AND SS FOR DISCHARGE STATION D–1, MAY 1975 THROUGH MARCH 1977.

contains a moderate amount of suspended matter, and is quite turbid. The discharge water has a similar suspended solids load, and tends to be lower than that of the supply water in the fall and winter, probably reflecting the deposition of silt in the reuse areas.

Figure V-4 shows EC to be inversely proportional to Q, while Fig. V-5 shows SS to be approximately proportional to Q. Presumably, at low flows, EC is higher than at high flows due to the predominance of subsurface drainage water over that of surface runoffs. Surface runoff is a major contributor to return flows and has lower EC than subsurface drainage or discharges of reused water. Suspended solids increase with increasing flows, presumably due to higher average water velocities, which tend to keep sediments in suspension.

Figure V-6 presents the relation between TDS and EC. EC is an intensive salinity parameter and is an electrical measurement of charged dissolved mineral salt species, while TDS is an extensive parameter and is a gravimetric measurement of dissolved inorganic and organic solids. In spite of these differences, the correlation coefficient (r) between EC and TDS was 0.99 and 0.91 for D-2 in the 1975 and 1976 irrigation seasons, respectively. Figure V-7 also presents the relationship between turbidity and SS. Turbidity is an intensive suspended matter parameter and is an optical measurement, while SS is an extensive parameter and is a gravimetric measurement. The r-values of 0.84 and 0.85 were obtained for D-2 in 1975 and 1976 irrigation seasons, respectively.

Appendix Table 14 contains a detailed analysis of the dissolved mineral salts in the NPDES and EPA stations for the months of March, June, and September of 1976 and January of 1977. The imported supply water from the Sacramento Valley via the Delta is low in salts, and its composition reflects the geochemistry of the watershed but due to admixture in the Delta from various sources they are slightly higher in Na, Cl, and SO_4 concentrations

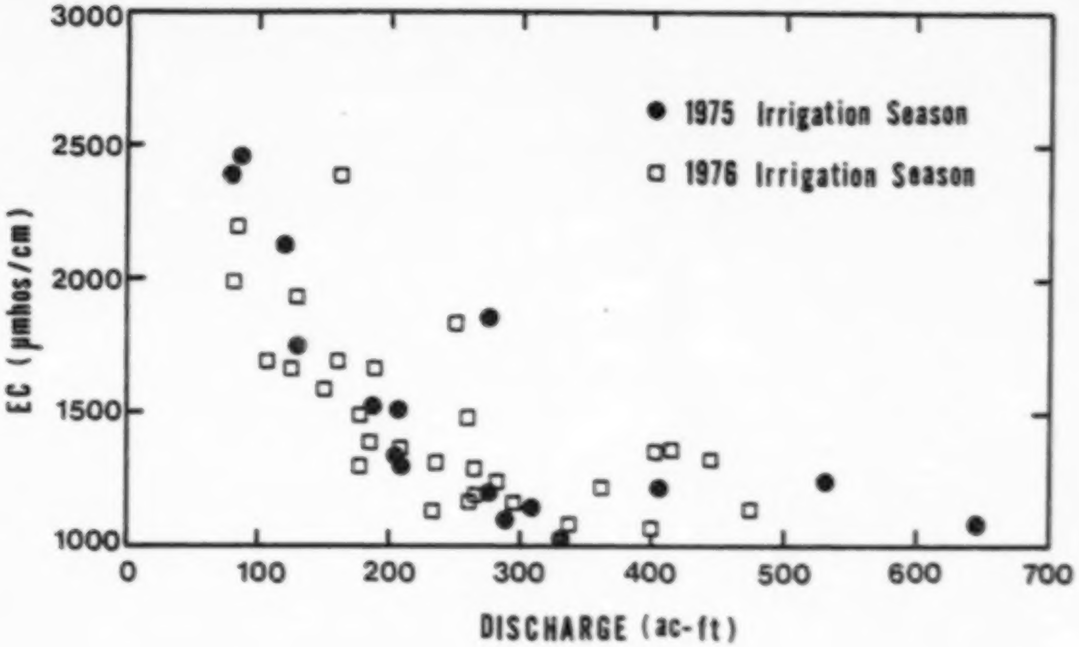


FIG. V–4: RELATION BETWEEN EC AND DISCHARGE FOR STATION D-1 FOR 1975 AND 1976 IRRIGATION SEASONS.

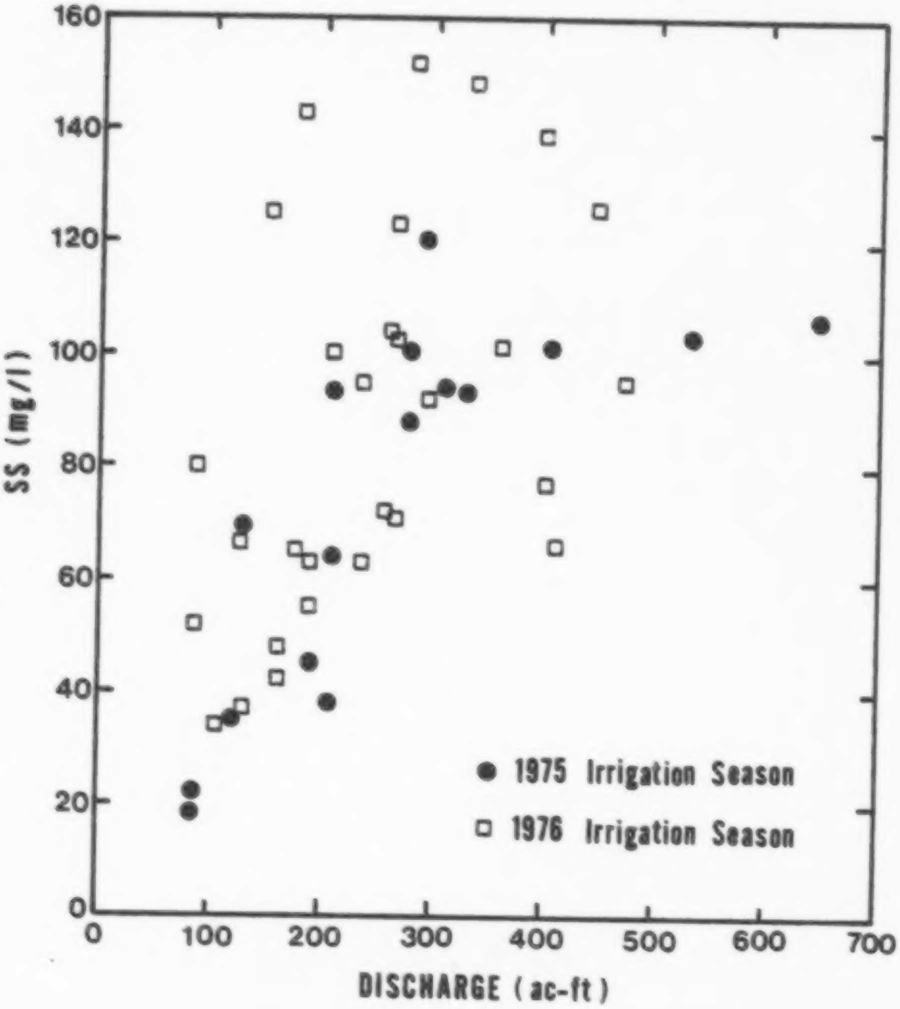


FIG. V—5: RELATION BETWEEN SS AND DISCHARGE FOR STATION D-1 FOR 1975 AND 1976 IRRIGATION SEASONS.

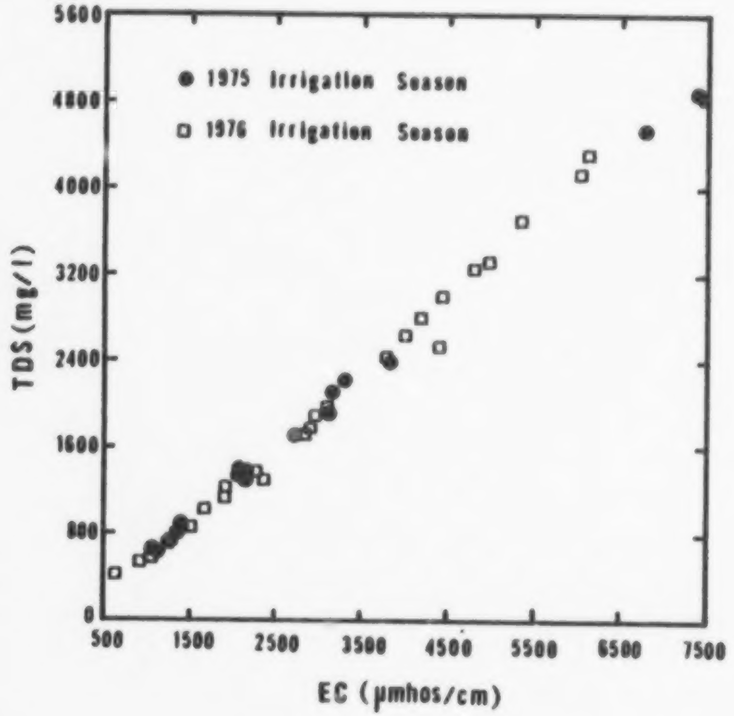


FIG. V-6: RELATION BETWEEN TDS AND EC FOR STATION D-2 FOR 1975 AND 1976 IRRIGATION SEASONS.

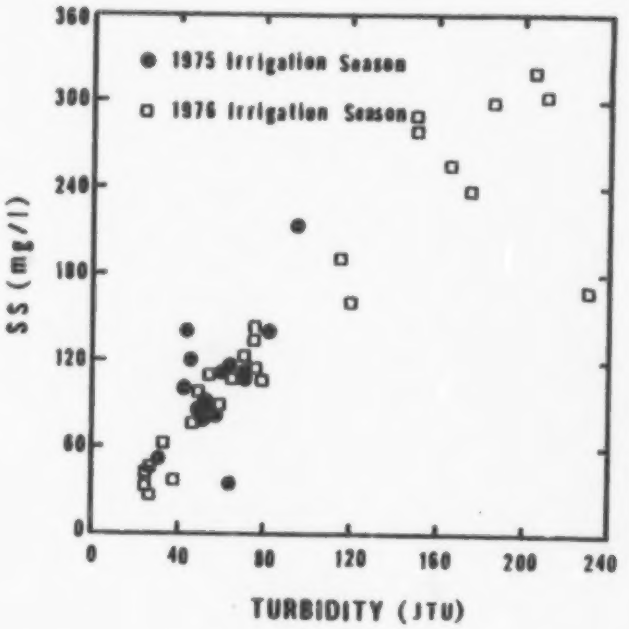


FIG. V-7: RELATION BETWEEN SS AND TURBIDITY FOR STATION D-2 FOR 1975 AND 1976 IRRIGATION SEASONS.

than in the Sacramento River. The composition and concentration of the discharge waters are significantly different from the supply water. Salinity is higher, in particular Na, Cl, and SO_4, due to the concentrating effects of evapotranspiration and salt pickup. This salt pickup occurs from the chemical weathering of the alluvial fill from the Coast Range, which is comprised of marine sedimentary rocks. Boron, another important elemental constituent of marine sedimentary rocks, is also high in concentration. Total Nitrogen (the sum of organic and mineral N species) ranged between 1.1 to 11.4 mg/liter, except for I-5, I-6, and I-9 which ranged from 11.3 to 52.6 mg/liter, respectively. For these high-N return flows, the dominant N species was 51.5, 18.3, and 15.4 mg/liter of nitrates, respectively. In other monitored stations, the organic-N and/or NO_3-N were the dominant species. It should be pointed out that the sources of N are manifold, including native soil N and fertilizer residues. BOD was about 0.6 mg/liter for most stations, except in areas draining wildlife and grassland habitats, where it ranged from 1.2 to 9.6 mg/liter. The higher BOD load is probably an indicator of animal (waterfowl, grazing animals, etc.) waste inputs into return flows. The pH for supply and internal stations ranged from 8.1 to 8.3 while in discharge waters it was 8.1 to 8.5. The DO level ranged from 8.9 to 12.0 mg/liter in all waters.

B. Broadview Water District

Broadview Water District has a unique water management practice in that this district has been literally "drinking all of its water." This 10,000 acre district has not discharged any of its surface return flows since 1956. Broadview Water District captures at Station BWD-3, Fig. V-8, all of the surface return flows generated within their district and some surface inflows from contiguous irrigated tracts of land (BWD-1 and BWD-2). All of these

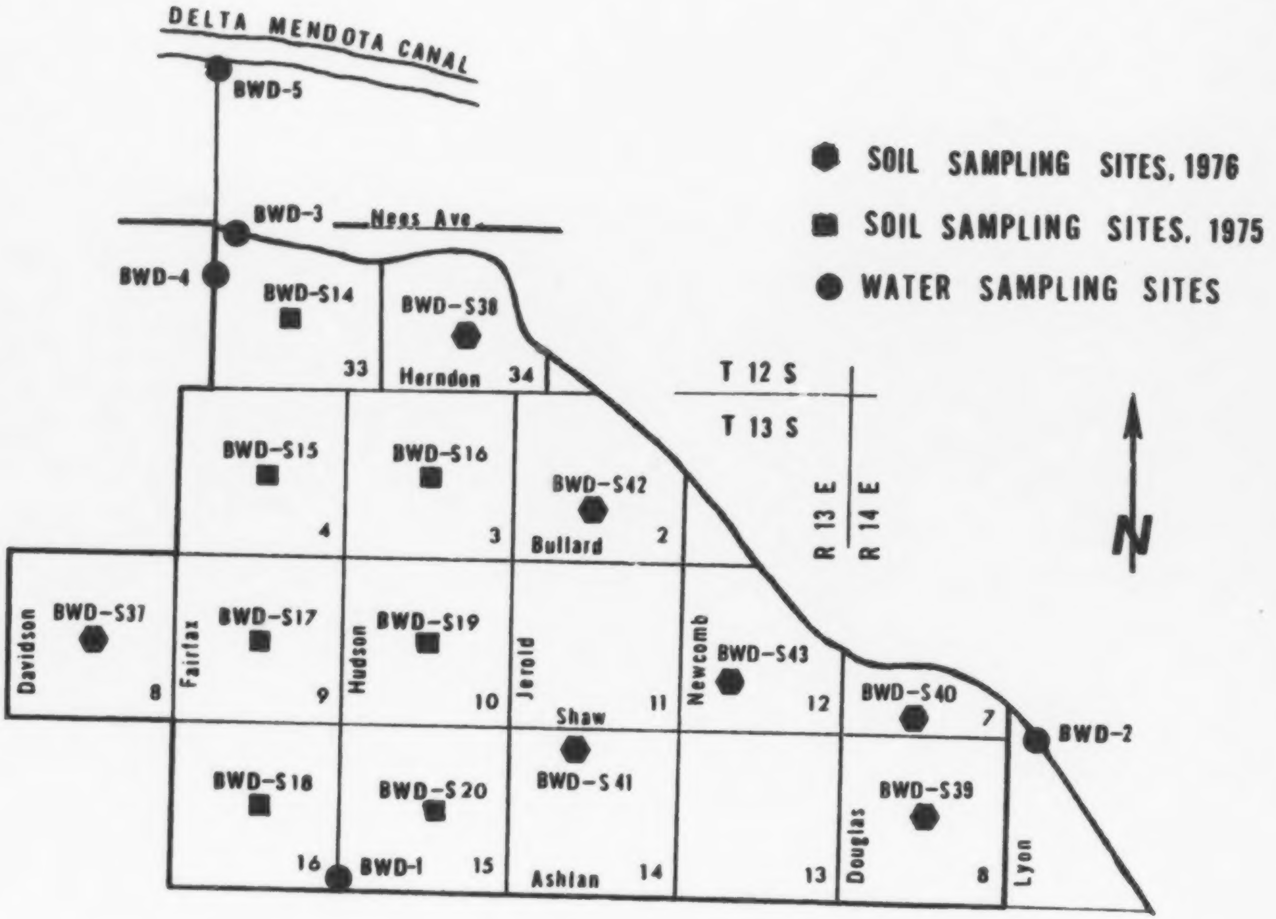

DELTA MENDOTA CANAL
BWD-5
BWD-3
Ness Ave.
BWD-4
BWD-S14
BWD-S38
33
Herndon
34
BWD-S15
BWD-S16
BWD-S42
4
3
Bullard
2
T 12 S
T 13 S
R 13 E
R 14 E
N
Davidson
BWD-S37
8
Fairfax
BWD-S17
9
Hudson
BWD-S19
10
Jerold
Shaw
11
Newcomb
BWD-S43
12
BWD-S40
7
BWD-2
BWD-S18
BWD-S20
BWD-S41
BWD-S39
16
BWD-1
15
Ashlan
14
13
Douglas
8
Lyon
⬢ SOIL SAMPLING SITES, 1976
■ SOIL SAMPLING SITES, 1975
● WATER SAMPLING SITES

FIG. V–8: BROADVIEW WATER DISTRICT
SOIL AND WATER SAMPLING SITES

return flows are pumped into the district main supply canal near BWD-3 and mixed with freshwater from the Delta-Mendota Canal obtained at BWD-5. Station BWD-4 characterizes the mixed supply water delivered to growers.

Table V-4 points out that Broadview Water District diverted 14,861 ac-ft of water from the Delta-Mendota Canal and delivered 28,132 ac-ft to growers in the calendar year 1976. The difference between these two quantities, 13,271 ac-ft, represents an estimate of drain water captured during 1976. Thus, the water delivered to growers is about a 53:47 mixture of fresh and drain waters. The average water application rate was estimated to be 3.13 ft (ac-ft/ac of cropland).

All of the EC's reported in Table V-4 are measured values while the FWA EC is the calculated flow-weighted average EC. A comparison between the calculated FWA EC and the measured EC ranges from -45% to +6%. These differences result because the measured EC's are obtained only once a month, and there are some errors in estimating flows. The FWA EC was computed solely to confirm the blend of about half-and-a-half supply water, based on quantity estimates.

Table V-5 presents the average water quality from monthly data reported in Appendix Table 16. The diverted canal water at BWD-5 is of good quality, but when blended with captured drain water (BWD-3), the mixed supply water at BWD-4 was considerably degraded in salinity and boron contents. Stations BWD-1 and BWD-2 are rim inflows from upslope irrigated lands. The latter is of poorer quality than the former; probably indicative of the presence of some collected subsurface drainage. The flows at BWD-1 and BWD-2 were measured with a water stage recorder and propeller meter, respectively.

Table V-6 gives estimates on mass transfers of TDS and SS. Column 3 contains the calculated difference between measured quantities found in delivered and diverted waters. This calculated difference should represent

Table V-4: Blend of Fresh and Return Flow Waters for Broadview Water District During 1976

Month	BWD-5		BWD-3		BWD-4			
	Q	EC	Q	EC	Q	EC	FWA EC	% Difference
January	1,584	-	976	-	2,560	-	-	-
February	2,801	384	2,026	1,889	4,827	1,275	1,016	-20
March	1,402	500	1,636	4,811	3,038	3,228	2,822	-13
April	788	390	1,279	3,517	2,067	3,643	2,325	-36
May	1,798	313	1,825	4,184	3,623	4,098	2,263	-45
June	2,676	475	2,219	2,474	4,895	1,612	1,381	-14
July	2,606	502	1,979	2,190	4,585	1,314	1,231	- 6
August	725	481	1,065	1,576	1,790	1,064	1,133	+ 6
September	24	424	36	3,897	60	3,786	2,508	-34
October	307	791	40	6,064	347	-	1,399	-
November	150	648	190	5,233	340	-	3,210	-
December	-	-	-	8,091	-	-	-	-
TOTAL	14,861	-	13,271	-	28,132	-	-	-

BWD-5 = Delta-Mendota Canal fresh water

BWD-3 = Captured drain water

BWD-4 = Delivered supply water containing fresh and drain water

Q = Water flow in ac-ft; Q for BWD-3 is difference between Q for BWD-4 and BWD-5

EC = Measured electrical conductivity in micromhos/cm

FWA EC = Calculated flow-weighted average EC

% Difference = Difference between measured EC and FWA EC

Table V-5 : Water Quality Data for Broadview Water District for 1976 (January through December)[†]

Station	Description	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH[*]
BWD-5	Diverted canal water	410	272	23	55	0.19	7.8
BWD-3	Captured drain water	2,986	2,085	175	283	2.19	7.6
BWD-4	Delivered mixed supply water	2,185	1,485	110	217	1.55	7.9
BWD-1	Contiguous surface inflow	601	322	1,149	930	0.32	8.2
BWD-2	Contiguous surface inflow	1,472	883	71	106	0.79	7.5

[†] Flow-weighted average

[*] July to December

Table V-6 : Estimated Mass Transfers of Salts and Sediments in Broadview Water District for 1976 (January through December)

	Delivered water (BWD-4)	Diverted canal water (BWD-5)	Calculated[*] difference	Captured drain water (BWD-3)
TDS, tons/year	56,815	5,497	51,318	37,631
TDS, lbs/ac[†]	11,981	1,159	10,822	7,936
SS, tons/year	8,302	1,112	7,190	5,108
SS, lbs/ac[†]	1,751	235	1,516	1,077

[*] (BWD-4)-(BWD-5)

[†] Based on 9,484 net acres of irrigated and nonirrigated land

the mass of salts and sediments in the captured drain water. However, the calculated difference in masses was found to be larger than the measured masses in the captured drain water by about 36 to 41%. These discrepancies may be partly attributed to the analysis presented in Table V-4. Nevertheless, Table V-6 points out that salts contained in the applied Delta-Mendota Canal water contributed nearly half a ton per acre, whereas the captured drain water contributed nearly 4 tons per acre, an increase of 1 ton per acre over last year. A similar analysis was made for suspended solids. The sediment brought into the district with the canal diversion was about 235 lbs per acre while captured drain water recirculated about 1,077 lbs per acre, which is about the same as last year.

Table V-7 contains a summary of soil salinity and soil boron data for seven sampling sites (Fig. V-7). The sampling locations and data for individual sampling sites are found in Appendix Tables 18, 19, and 20. These sampling sites were sampled to the water table from 7 to 16 feet beneath the land surface, which is 2 to 3 feet deeper than last year. The Panoche soil series is predominant in this area, with textures ranging from loam to clay. The surface 1/2-ft depth was salt-affected with EC_e (EC of saturation extract) ranging from 1.5 to 9 millimhos/cm. Estimates of total soluble salts in tons per ac-ft of soil were made from EC_e and saturation percentage, the reference soil-water content used to extract the soil solution in the laboratory. Gypsum, $CaSO_4 \cdot 2H_2O$, was also measured. It is a naturally occurring mineral that contributes to soil salinity. Gypsum was exceedingly high in five out of seven sites, exceptions being BWD-S38 and BWD-S40 in Fig. V-7. The average boron data, was representative of the seven sites.

Appendix Table 17 gives the detailed analyses on dissolved salt constituents for the water sampling stations. The captured drain water was highly

Table V-7:

Summary of Soil Data (average cf 7 sites) - Broadview Water District

1976

Depth (ft)	EC_e (mmhos/cm)	Estimated soluble salts (tons/ac-ft soil)	Gypsum (tons/ac-ft soil)	Boron (mg/ℓ)
0-½	4.63	3.82	1.45	2.08
½-1	5.71	4.50	2.94	2.09
1-2	6.70	5.60	4.58	2.92
2-3	8.62	7.25	30.43	3.23
3-4	9.09	8.23	29.26	3.56
4-5	8.86	8.36	26.70	3.49
5-6	8.55	8.28	31.17	4.05
6-7	8.27	8.06	28.82	4.65
7-8	8.82	8.23	45.78	6.26
8-9	7.78	6.90	33.07	5.62
9-10	7.39	5.30	23.25	3.53
10-11	7.59	5.25	22.33	3.67
11-12	7.19	5.72	26.96	3.60
12-13	8.30	6.80	24.64	3.97
13-14	10.13	6.69	16.63	3.79
14-15	12.97	6.41	8.46	3.95
15-16	13.68	5.76	7.26	4.15

saline, containing largely Na, Cl, and SO_4, 2 to 3 times higher than last year. The mix of freshwater and drain water delivered to growers also contained the above mentioned three ions as the dominant ones, 3 to 4 times higher than last year. The analysis for nitrogen in these waters showed Total Nitrogen ranging from 13.6 to 22.8 mg/liter in the drain water (BWD-3), 1.1 to 2.1 mg/liter in the diverted canal water (BWD-5), and 7.4 to 15.4 mg/liter for the mixed supply water (BWD-4). The dominant N species were NO_3-N and Organic N. BOD ranged from 0.6 to 3.0 mg/liter, and DO ranged from 8.9 to 11.2 mg/liter.

Table V-8 contains the 1976 cropping pattern and average yield. Cotton, tomatoes, wheat, and barley were the major crops grown. In spite of the comparatively poor supply water quality due to the reuse of surface and subsurface return flows, the salinity in the surface soil and the crop yields appear to be unaffected. How long this trend will persist is not known.

C. Panoche Water District

The 44,000 acre Panoche Water District, Fig. V-9, was another entity studied in the Mendota-Crows Landing Return Flow Group. In contrast to Broadview Water District, this district does have a surface discharge outlet. Some of the drain water produced in the Panoche Water District is reused at the field and farm sites, and some is pumped into the CCID Outside Canal. But most of the drain water from the district is discharged through Panoche Drain (I-6) into the grassland and wildlife habitats, where extensive reuse occurs.

In addition to district-wide assessments, on-farm studies were conducted in a 170 acre tomato/lettuce/melon field and on a 1,675 acre tile-drained farm, indicated by the shaded portions in Fig. V-9. A U.S. Weather Bureau Class A evaporation pan was also installed in an irrigated pasture near the

Table V-8: Crop and Yield Report for the Broadview Water District during the 1976 Irrigation Season.

Crop	Acres Harvested	Average Yield per Acre
Cotton	3,176	2.36 bales
Barley	1,073	2.46 tons
Alfalfa Seed	887	526.38 pounds
Melons	300	220.00 cartons
Tomatoes	1,967	22.51 tons
Sugar Beets	521	32.69 tons
Wheat	1,050	2.00 tons
TOTAL	8,974	

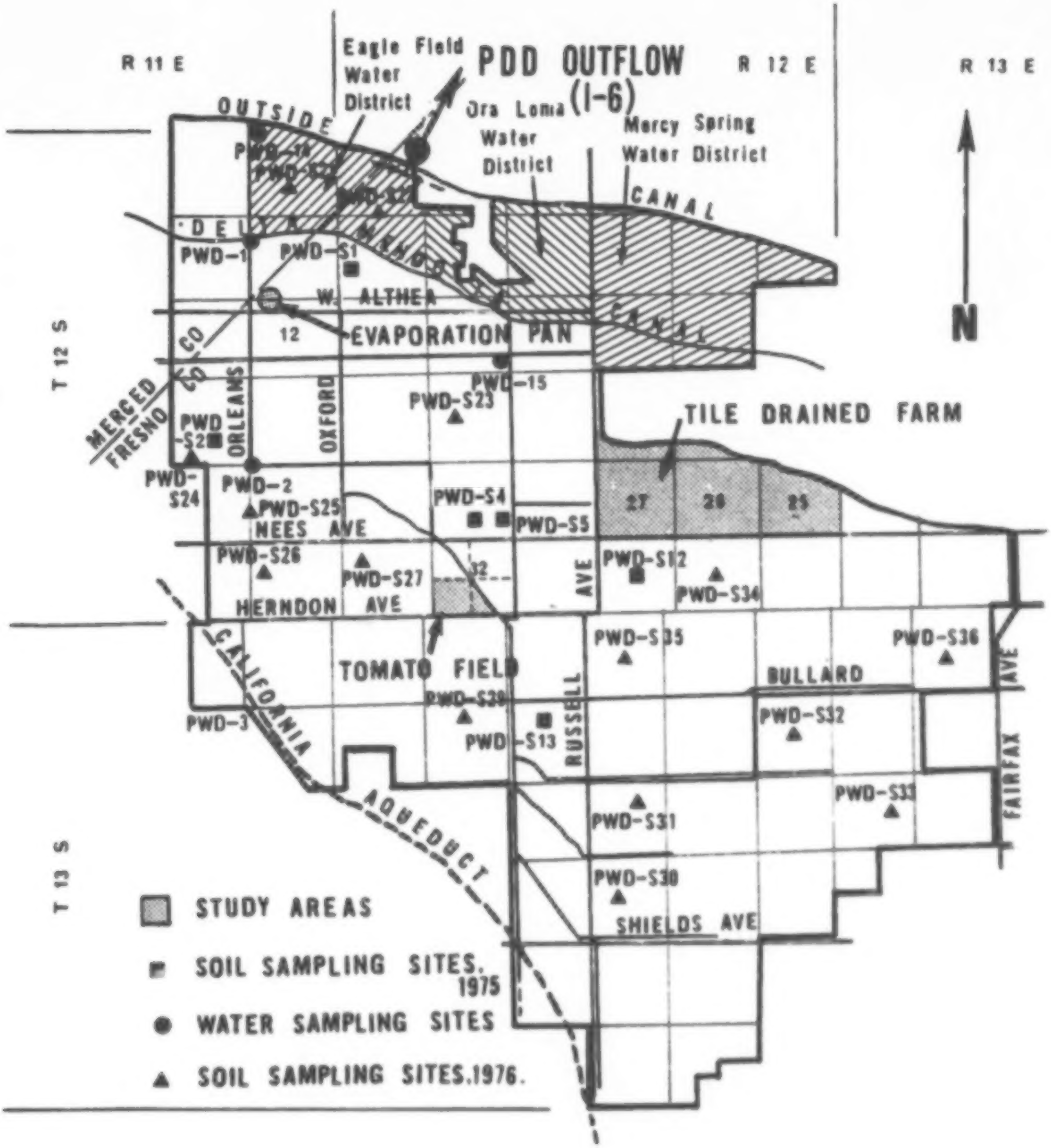

R 11 E
Eagle Field Water District
PDD OUTFLOW (I-6)
R 12 E
R 13 E
OUTSIDE
Ora Loma Water District
Mercy Spring Water District
CANAL
DELTA MENDOTA CANAL
PWD-1
PWD-S1
W. ALTHEA
12
EVAPORATION PAN
T 12 S
N
MERCED CO
FRESNO CO
PWD-S2
ORLEANS
OXFORD
PWD-15
PWD-S23
TILE DRAINED FARM
PWD-S24
PWD-2
PWD-S25
NEES AVE
PWD-S4
PWD-S5
27
26
25
PWD-S26
PWD-S27
32
HERNDON AVE
AVE
PWD-S12
PWD-S34
CALIFORNIA AQUEDUCT
TOMATO FIELD
PWD-S35
PWD-S36
BULLARD
AVE
PWD-3
PWD-S28
PWD-S13
RUSSELL
PWD-S32
FAIRFAX
PWD-S33
PWD-S31
T 13 S
PWD-S30
SHIELDS AVE
▨ STUDY AREAS
■ SOIL SAMPLING SITES, 1975
● WATER SAMPLING SITES
▲ SOIL SAMPLING SITES.1976.

FIG.V-9 : PANOCHE DRAINAGE DISTRICT STUDY AREAS, SOIL AND WATER SAMPLING SITES.

Panoche Water District office, to obtain estimates on potential evapotranspiration rates for this study area.

Panoche Water District is one of four entities in the Panoche Drainage District. The other three entities are the Ora Loma Water District, the Eagle Field Water District, and part of the Mercy Springs Water District located in the vicinity of the Delta-Mendota Canal and the Outside Canal (Fig. V-9). Irrigation return flows from all of these four entities are discharged into Panoche Drain.

Table V-9 presents data on water inflows and outflows, and analyses of their relationships for the period January through December, 1976, in the Panoche Drainage District. Panoche Water District has two sources of imported waters, the Delta-Mendota Canal and the California Aqueduct. The quantities of purchased and delivered water are reported, and if the difference between them is positive, this gives an estimate of captured return flow; if the difference is negative, this gives an estimate of seepage and other losses. For 1976 the net captured return flow was estimated at 4,304 ac-ft, or 3.6% of the total purchased water, for Panoche Water District.

A similar analysis is not available for the other three water districts. Eagle Field, Mercy Springs, and Ora Loma Water Districts obtain their supply water from the Delta-Mendota Canal and some from the Outside Canal. The total supply water for all entities in the Panoche Drainage District was 135,523 ac-ft.

With regards to the discharge of surface return flows, approximately 19% was pumped directly into the supply canal for CCID, while the remainder was discharged into the Panoche Drain (I-6). An analysis of supply-discharge relations gives a surface drainage index of 0.31; i.e., surface drainage is 31% of Panoche Drainage District's supply water, in contrast to 0% for the Broadview Water District. The unit applied water in Panoche Drainage District

Table V-9: Supply and Discharge Waters (in acre-feet) for Panoche Drainage District During the Period January Through December 1976.

Supply Water	Purchased Water	Delivered Water	Recaptured Water
Delta-Mendota Canal water	69,468	76,132	6,664
California Aqueduct water	49,003	46,643	-2,360
Subtotal for Panoche Water District	118,471	122,775	4,304
Other Districts*, Delta-Mendota Canal water and outside canal	17,052		
Total supply	135,523		
Discharge Water	Discharge Water		
Panoche Drain (I-6)	33,398		
Captured by Central California Irrigation District	7,970		
Total Outflow	41,368		

Supply-Discharge Relations

Surface Drainage Index = Discharge/Supply =41,368/135,523 = 0.31

Unit Applied Water = Supply/Irrigated Acres = 135,523/37,835 = 3.58

Unit Surface Drainage = Discharge/Net Acres = 41,368/43,762 = 0.95

---

* Mercy Springs Water District = 2,272 acres, 8,490 ac-ft

Ora Loma Water District = 1,180 acres, 4,775 ac-ft

Eagle Field Water District = 1,400 acres, 3,787 ac-ft is estimated to be 3.58 ft as compared to Broadview Water District's 2.27 ft, while the unit surface drainage is estimated to be 0.95 ft in the former district.

Two more stations were added to the sampling program in February, 1976. Both these stations (PWD-14 and PWD-15) are on the Northside and Courtney drains, respectively. The need for recapture and reuse of more drain water on the district level made it necessary to add these stations for quality control purposes.

Table V-10 gives the flow and water quality for Panoche Water District for January through December of 1976, which summarizes the data presented in Appendix Tables 22, 24 for PWD-13E and 26 for PWD-14 and 15. The district supply waters are of good quality. EC and TDS values in both supply waters are slightly higher than last year. Suspended matter is lower in the California Aqueduct, probably due to impoundment in the San Luis Reservoir and conveyance in the concrete-lined canal system. The district return flow in Panoche Drain was about six times more saline than the supply water. Such a large increase in salinity can only be attributed to the leaching of native salts present in the soils. In addition, boron and suspended matter in the discharge water are very high when compared to the supply water. All of these observations are a reflection of the chemical and physical properties in the area; i.e., the soils are salt-affected and highly susceptible to erosion. Four other stations (PWD-2, PWD-13E, PWD-14, and PWD-15) were sampled and these represent internal points in the Panoche Water District. PWD-2 is on the supply canal which conveys Delta-Mendota Canal Water from PWD-1 by a series of lift pumps. Some admixture of return flows takes place as the freshwater is lifted. This observation is supported by the increases in salinity indicated by EC and TDS and boron. PWD-13E is located on Hammond Drain, shown on the map of the tile-drained farm (Fig. V-10). The quality of

Table V-10: The 1976 (January through December) Flow and Quality in the Panoche Water District.

Station	Description	Q (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
Supply Stations:								
PWD-1	Delta-Mendota Canal Water	69,468	448	268	30	56	0.14	8.0
PWD-3	California Aqueduct Water	49,003	448	266	13	14	0.11	8.2
Discharge Station:								
I-6	Panoche District Drain	33,398	2,765	1,885	170	306	4.03	8.0
Internal Stations:								
PWD-2	Supply Canal at Lift #4	46,441	745	439	38	81	0.50	8.0
PWD-13E	Hammond Drain*	179	1,857	1,301	136	245	2.37	7.9
PWD-14	Northside Drain†	--	3,420	2,314	58	117	5.04	8.1
PWD-15	Courtney Drain†	--	3,034	2,051	120	267	4.84	8.1

* The flow Q is water pumped by the farm and not actually in the drain. The quality parameters are based on these flows.

† February through December 1976. No flows available. Straight averages.

this return flow is similar to that of Panoche District Drain which is located farther downstream in the drainage network. PWD-14 and PWD-15 are both on the drains, as mentioned earlier, which are much higher in salinity than PWD-2 or PWD-13E. This is because both these stations are mostly fed by the tile drains. Boron content in these two stations is also higher. The water quality of these two stations is more or less comparable to I-6, i.e., outflow from the district.

Appendix Tables 23, 25 and 27 contain additional water quality data for these district and on-farm stations in the Panoche Water District for March, June, September, 1976, and January, 1977. Evidences for the water being lifted from PWD-1 to PWD-2 as receiving return flow inputs are noted by increases in Na, Ca, Cl, SO_4, Total N and NO_3-N. The water samples obtained from PWD-13E for detailed analyses inadvertently were for the months in which drain waters were least saline (Appendix Table 22). Nevertheless, substantial pickup in almost all constituents is noted when comparing PWD-13E, PWD-14, and PWD-15 to either PWD-1 or PWD-3. It is of interest to note that Total N at PWD-13E during the monitored months consisted mostly of nitrogen in nitrate form. BOD results were similar to those found in Broadview Water District's return flows.

Figure V-10 shows a plot of electrical conductivity for Panoche Drain Outflow (I-6) for September and early October as measured by a constant EC recorder. The EC varied between 2200 and 5000 micromhos/cm. Towards the end of September the EC values went up because of more leaching of salts due to some precipitation. On the average, the EC for the whole year was 2800 μmhos/cm.

Table V-11 presents the average of all soil data obtained in Panoche Water District. Data for 16 soil sampling sites (Appendix Table 28) are found in Appendix Table 29, and sampling sites are noted in Figs. V-8 and

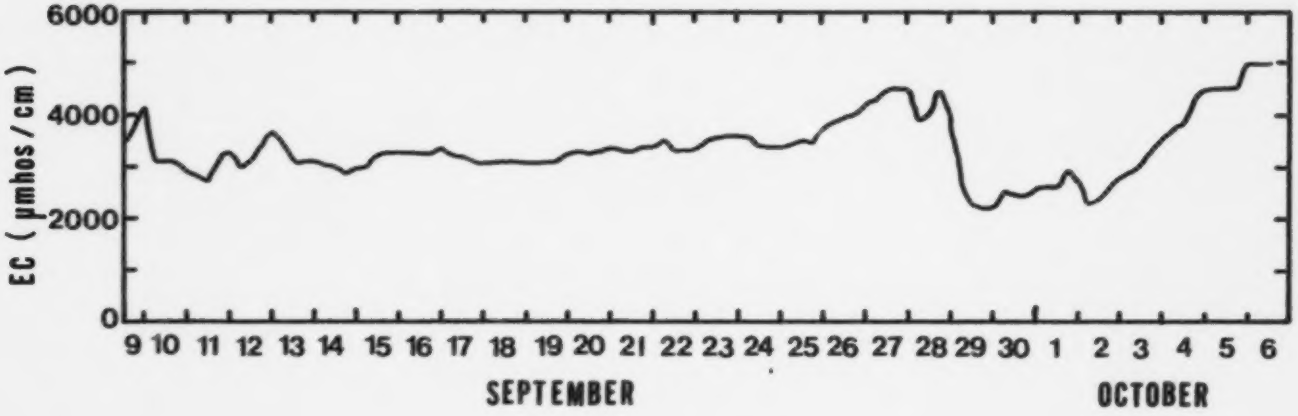


FIG. V-10: PLOT OF ELECTRICAL CONDUCTIVITY FOR PANOCHE DISTRICT DRAIN (I–6) DURING SEPTEMBER AND OCTOBER, 1976.

Table V-11:

Summary of Soil Data (average of 16 sites) - Panoche Drainage District

1976

Depth (ft)	EC_e (mmhos/cm)	Estimated soluble salts (tons/ac-ft soil)	Gypsum (tons/ac-ft soil)	Boron (mg/ℓ)
0-½	2.73	1.89	0.73	1.21
½-1	2.85	1.94	0.76	1.24
1-2	2.42	1.82	1.07	2.12
2-3	2.74	1.97	2.62	2.45
3-4	3.05	2.11	4.19	2.57
4-5	3.46	2.36	7.19	2.14
5-6	3.35	2.46	8.59	2.28
6-7	3.29	2.47	9.98	2.58
7-8	3.48	2.57	11.08	2.08
8-9	3.63	2.71	13.11	3.09
9-10	3.46	2.64	13.46	2.92
10-11	3.58	2.53	18.82	3.10
11-12	2.75	2.01	14.98	1.56
12-13	2.94	2.12	13.36	1.62
13-14	2.86	2.07	12.66	1.69
14-15	2.85	2.16	11.20	1.66
15-16	2.64	1.77	6.95	1.59
16-17	3.00	2.13	11.45	1.90
17-18	1.91	1.23	9.95	1.11
18-19	2.10	1.24	4.77	1.11
19-20	1.70	0.95	2.64	1.37
20-21	1.91	1.04	2.81	1.41
21-22	1.95	1.14	1.61	1.17
22-23	2.38	1.49	1.83	1.29
23-24	2.68	1.38	3.28	1.47
24-25	3.25	1.44	0.25	1.93
25-26	0.73	0.35	0.22	1.50
26-27	0.74	0.28	0.22	2.00

V-11. When comparing this average data with the average for Broadview Water District, it is noted that the surface soils are less saline in Panoche than in Broadview Water District. In Panoche Water District, more gypsum is present in the 5-18 ft depths than others, while in Broadview Water District, significant amounts exist throughout the soil profile. Boron is higher in Broadview Water District throughout the soil profile than in Panoche, while the reverse was true for last year. Closer examination of Appendix Table 29 shows that some sampling sites were relatively salt-free, while others were highly salt-affected. The Cl data gives an indication of the leaching patterns in these sites since it is assumed to be non-reactive with regards to ion exchange and mineral dissolution, or precipitation.

Table V-12 contains a crop and yield report. The total crop average was about 4,000 acres smaller than 1975. Like Broadview Water District, cotton, tomatoes, barley, and melons are the major crops in Panoche Water District. The crops are more diverse in number. As in Broadview Water District, in spite of the presence of salt-affected soils and some reuse of saline and boron-containing return flows, the crop yields were not greatly affected.

Tile-Drained Farm

Figure V-11 contains a map of the 1,675 acre tile-drained farm studied in the Panoche Water District. With the assistance of the Soil Conservation Service, the grower started developing a subsurface drainage system in the fall of 1968. Plans called for an eventual 1,100 acres to be tile-drained, starting with the first 670-acre tract in the eastern portion of the farm. For this first 670 acres, about 61,700 lineal ft of 6-12" concrete tile was installed at 600 ft lateral spacing and at a 7 ft soil depth, and then backfilled with a sand-gravel mix. It had a design capacity of 2.61 cfs. The tile effluents were collected in a sump at PWD-12E. Since then, the work

Table V-12:

Crop Report for Panoche Water District

Mendota-Crows Landing Return Flow Group

1976

CROPS	ACRES HARVESTED	AVERAGE YIELD PER ACRE
Almonds	90	1,000 lbs
Alfalfa Hay	724	8,788 lbs
Alfalfa Seed	388	129 lbs
Barley	2,871	2.32 tons
Beans	700	1,333 lbs
Cantaloupes	1,908	250 cartons
Carrot Seed	206	337 lbs
Corn	676	15 tons
Cotton	14,477	2.07 bales
Crenshaws	240	700 cartons
Garlic	80	18,500 lbs
Garlic	38	74.0 cartons
Honeydews	210	600 cartons
Lettuce	544	613 cartons
Oats	676	9 tons
Pasture	157	
Safflower	467	1.35 tons
Tomatoes	4,302	23.98 tons
Peppers	101	1.2 tons
Wheat	947	2.4 tons
Sugar Beets	737	29.56 tons
Rice	140	34 sacks
TOTAL	30,979	

Area Not Harvested	2,004 acres
Area Double-Cropped	1,136 acres
Area in Fallow	120 acres
Area Non-Cropped	965 acres
Water Other than Project Water	450 acres

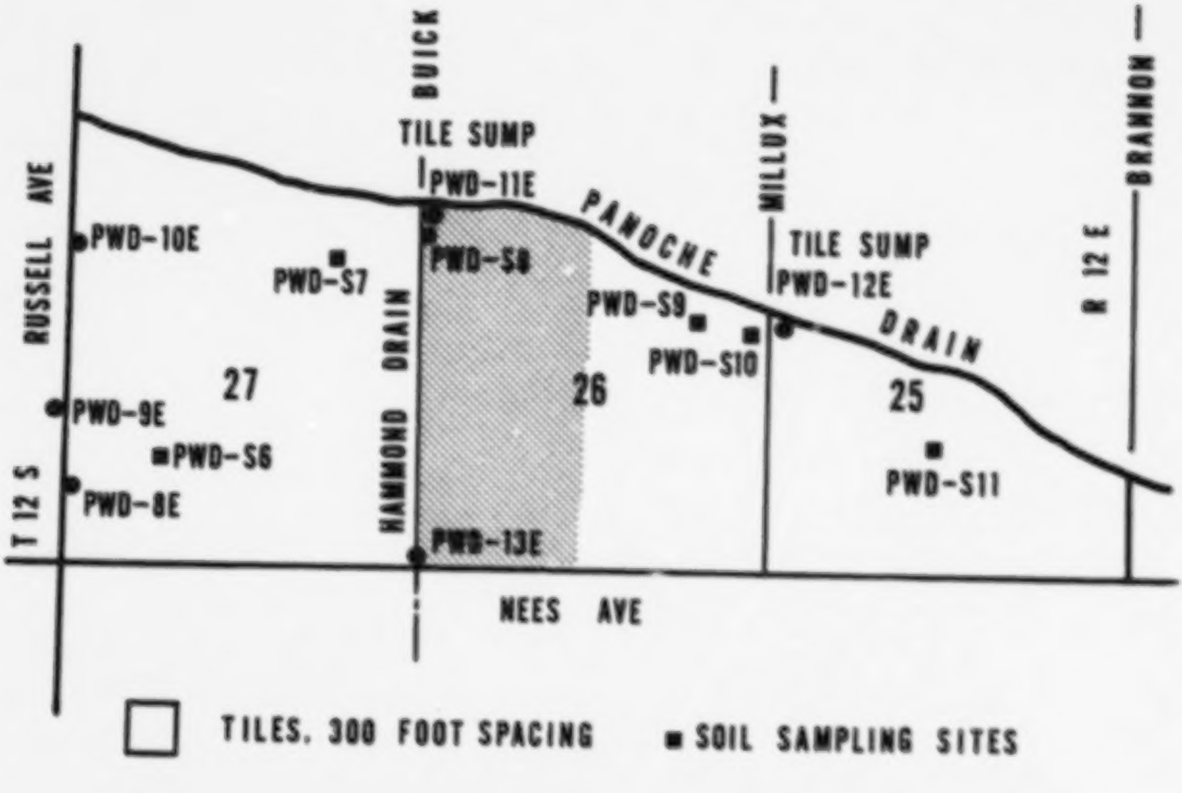

BUICK
TILE SUMP
PWD-11E
PANOCHE DRAIN
MILLUX
TILE SUMP
PWD-12E
BRANNON
R 12 E
RUSSELL AVE
PWD-10E
PWD-S7
PWD-S8
HAMMOND DRAIN
PWD-S9
PWD-S10
27
26
25
PWD-9E
PWD-S6
PWD-8E
T 12 S
PWD-13E
PWD-S11
NEES AVE
TILES, 300 FOOT SPACING
TILES, 600 FOOT SPACING
■ SOIL SAMPLING SITES
● WATER SAMPLING SITES

FIG. V-11: TILE DRAINED FARM IN PANOCHE WATER DISTICT. SOIL AND WATER SAMPLING SITES.

plans for subsurface drainage have been progressing steadily. In 1971, however, the grower made a change from the original design, substituting 4" corrugated plastic for the 6" concrete laterals. Recommended spacings were from 240-300 ft, but the grower used 600 ft spacing, with the intention of adding another lateral between the 600 ft spacing after a hydraulic check. More recently, 8" corrugated plastic lines are being installed instead of 10" concrete baseline tile, and during the last two years, the spacing has been reduced from 600 ft to 300 ft except for about 300 acres which will be finished in the next couple of years or so. Figure V-11 shows the extent of tile drainage to date and the lateral spacings.

Tile effluents are collected in two sumps, at PWD-12E and PWD-11E, and discharged into the Panoche Drain. This drainage water, which includes collected surface and subsurface waters from this farm and others upslope, flows in a northeasterly direction and some of it is captured at PWD-10E, mixed with freshwater from PWD-9E, and then used for irrigation in the tile-drained farm. Station PWD-8E represents the mixed supply water. In addition, minor amounts of drain water are also pumped from Hammond Drain at PWD-13E and reused.

Table V-13 gives water flow data for the calendar year 1976. The freshwater supply consisted of 4,746 ac-ft, which was mixed with 2,411 ac-ft of drain water. Another 179 ac-ft was captured and reused from Hammond Drain. The tile sumps discharged about 723 ac-ft during 1976.

Table V-14 presents the flow and flow-weighted quality data for January through December of 1976. The Delta-Mendota Canal water at PWD-9E was of good quality. The drain water captured at PWD-10E was saline, and contained about 2 mg/liter of boron. The resultant mixed supply water had an average EC of about 1,260 µmhos/cm, and 1.2 mg/liter boron. Based on our quantity data, it appears that the supply water was a blend of 34:66 of

Table V-13: 1976 Calendar Year Water Flows in Acre-Feet for the Tile Drained Farm in Panoche Water District.

Month	PWD-9E fresh water	PWD-10E captured drain water	PWD-8E mixed supply water	PWD-11E tile drainage effluent	PWD-12E tile drainage effluent	PWD-13E Hammond Drain
Jan	420	143	563	19	5	2
Feb	651	85	736	36	28	0
Mar	975	329	1,304	50	98	34
Apr	439	124	563	25	51	1
May	721	267	988	39	43	36
June	273	408	681	39	36	3
July	280	418	698	21	14	84
Aug	177	130	307	18	9	2
Sept	0	14	14	8	2	0
Oct	456	297	753	6	36	16
Nov	354	196	550	23	85	1
Dec	0	0	0	8	24	0
Total	4,746	2,411	7,157	292	431	179

fresh and captured drain waters. As expected the tile effluents collected at PWD-11E and PWD-12E were extremely saline (between 8,000 and 10,300 umhos/cm) high in boron (between 9 and 20 mg/liter), and low in suspended matter. Hammond Drain at PWD-13E was of poorer quality than Panoche drain at PWD-10E as evidenced by the higher salinity, boron, and SS concentrations. Based upon the data presented in Table V-14, 2,498 tons of salts were brought in with the fresh supply water, and 7,001 tons of salts were recirculated with the captured drain water.

Table V-15 indicates the crops grown in 1976 and their yields, similar to the district (Table V-12), but note that the yields of crops in this farm are higher than those at the district level.

Furrow-Irrigated Lettuce/Melon Field

Figure V-12 gives a layout of the 170 acre lettuce/melon field in Panoche Water District. This field had tomatoes in 1975 and was monitored for tailwater production and recovery. During the winter (November, 1975, to March, 1976) this field was planted to lettuce in the north-south direction in furrows as indicated by the arrows. The supply water was obtained from the California Aqueduct through PWD-4T and from Delta-Mendota Canal at PWD-6T. During the initial stages of germination, 3 different methods of irrigation; namely, furrow irrigation with siphons, gated pipe, and sprinkler system were used all at the same time. The sprinklers were used to keep the surface soil from forming a hard crust while the furrow irrigation kept the root zone moist. Later on when the crop stand was well established, the water was applied only by furrow irrigation. Since the field was constantly being irrigated, significant amounts of tailwater were produced, which was recycled through the return pump at PWD-7T. Due to the nonavailability of accurate information on the flows, the irrigation practice could not be fully evaluated.

Table V-14: Water Flow and Flow-Weighted Water Quality Parameters for 1976 (January through December) in the Tile Drained Farm.

Stations	Description	Q (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
PWD-9E	Fresh Water	4,746	387	235	22	27	0.11	8.5
PWD-10E	Captured Drain Water	2,411	2,135	1,425	87	157	2.18	7.6
PWD-8E	Mixed Supply Water*	7,157	1,264	814	44	55	1.10	8.1
PWD-11E	Tile Effluent	292	10,295	8,212	5	7	19.95	7.7
PWD-12E	Tile Effluent	431	7,965	6,109	5	17	8.66	7.8
PWD-13E	Hammond Drain	179	3,647	2,572	247	444	4.71	7.9

*The flow is for full year but the flow weighted averages represent water quality when actual mixing of fresh and drain water occurred.

Table V-15:

Crop Report for Tile Drained Farm in Panoche Water District
Mendota-Crows Landing Return Flow Group
1976

Crop	Acres Harvested	Average Yield per Acre
Beans	375	1500 lbs
Cotton	641	2.6 bales
Barley	221	2.5 tons
Wheat	400	2.5 tons
TOTAL	1,637	

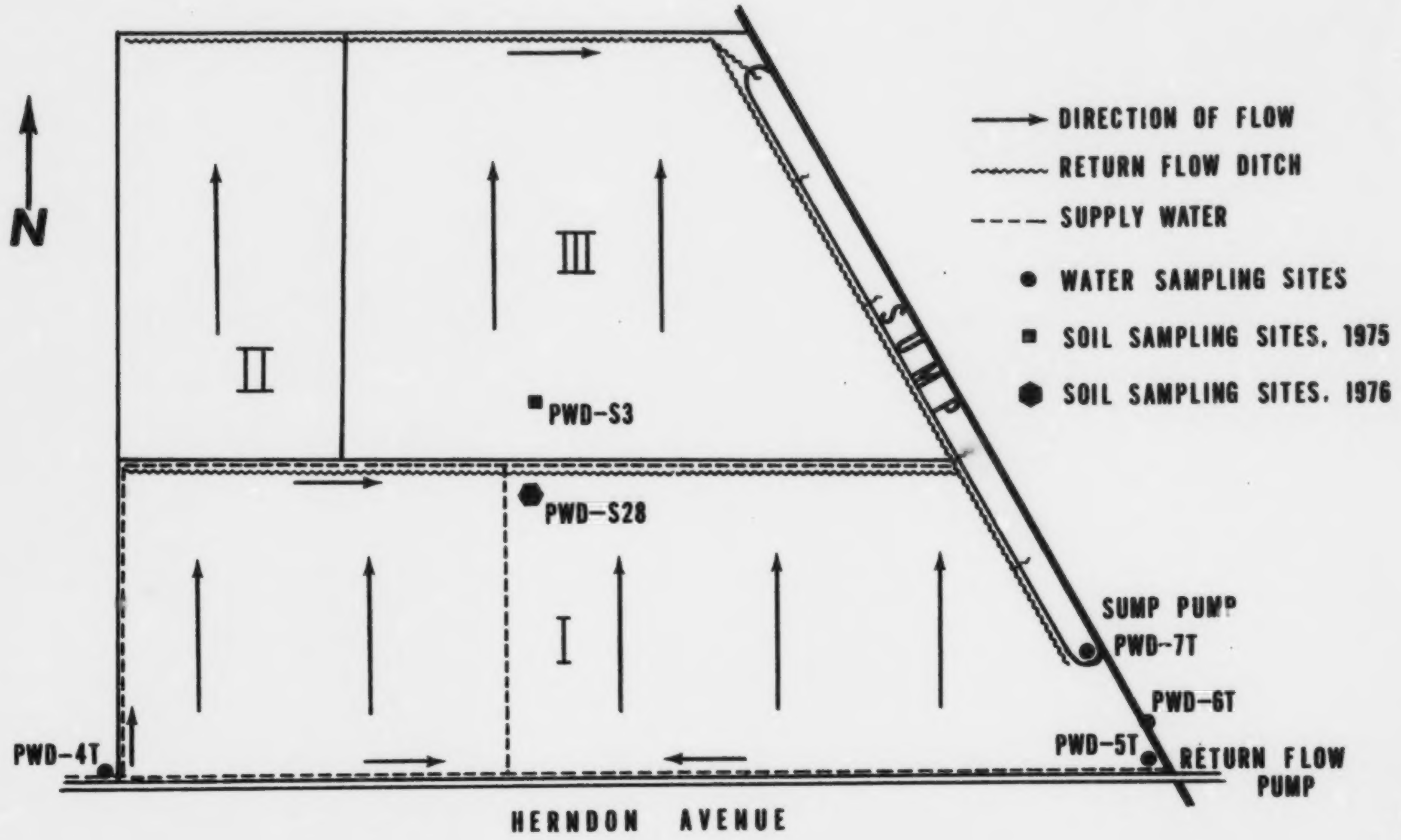

N
DIRECTION OF FLOW
RETURN FLOW DITCH
SUPPLY WATER
WATER SAMPLING SITES
SOIL SAMPLING SITES, 1975
SOIL SAMPLING SITES, 1976
II
III
I
SUMP
PWD-S3
PWD-S28
SUMP PUMP
PWD-7T
PWD-6T
PWD-5T
RETURN FLOW PUMP
PWD-4T
HERNDON AVENUE

FIG. V-12: FURROW IRRIGATED, 170 ACRE LETTUCE/MELON FIELD,

PANOCHE WATER DISTRICT, 1976 IRRIGATION SEASON.

The lettuce crop was followed by honeydew melons. The direction of irrigation and the sources of supply water were the same as for lettuce, but the field was divided into three subfields for cultural operations, as shown in Fig. V-12. Subfields I and II were planted at the same time but subfield III was planted a month later to stagger the harvest timings. Subfields I and II were irrigated by siphons and subfield III was irrigated by gated pipe and used most of the recovered tailwater along with the freshwater. A detailed monitoring of water quality and flow could not be done because of irrigation schedules and other technical difficulties. However, a small analysis of flows was made in subfield III, which is about 60 acres, during the last two irrigations during August and September. In each irrigation, equal amounts of water (25 ac-ft or 5.0 inches) was applied, which produced about equal amounts of tailwater (5 ac-ft or 1.0 inch). During the August irrigation and the ones before that, all the tailwater produced was reused but the tailwater produced during the September irrigation was not reused as it was the last irrigation of the season. This is not a common practice but an individual's preference. These two tests reveal that 20% of the water was recycled within the field. The quality of melons grown in this field was not as good as expected because of excessive amounts of nitrogen left in the field from the previous crop (lettuce). The size of melons grew bigger than desired and took longer to ripen, resulting in a poorer quality than usually expected.

D. Los Banos Wildlife Area

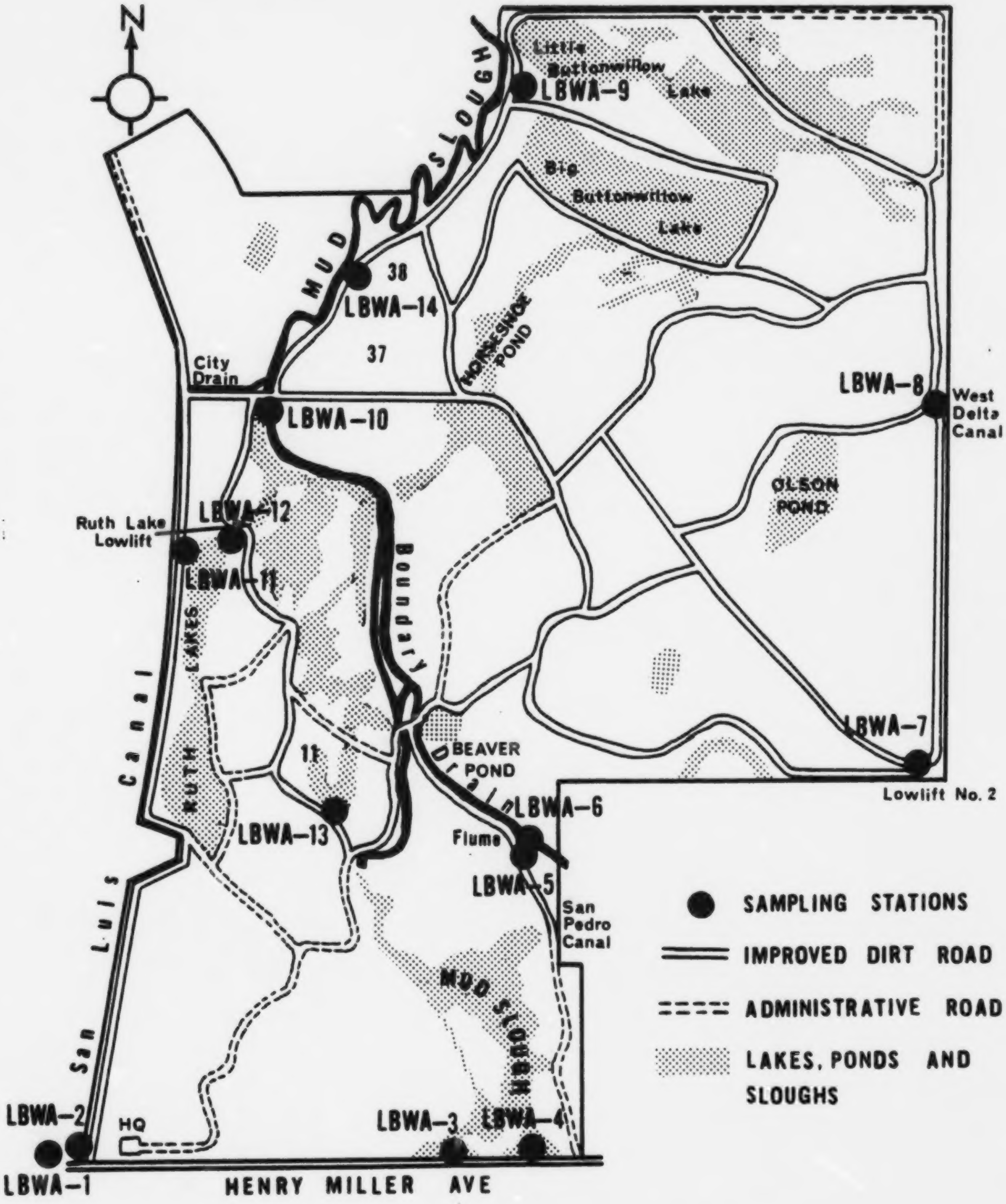
Within the Mendota-Crows Landing Return Flow Group a mutually beneficial arrangement has evolved among the various water users. During the irrigation season, part of the irrigation return flow generated by crop irrigators is utilized for the irrigation of pastures (grassland) which are grazed by cattle, and to provide suitable wildlife habitats, including wetlands. On the other hand, during the nonirrigation season, the distribution system used for conveying irrigation water is utilized for delivering freshwater to flood portions of the grasslands and wildlife refuges, for wintering waterfowl. Historically, there were about 5 million acres of permanent to semipermanent marshlands in the Central Valley, but now it has been reduced to about 1 million acres. Since 25% of all migratory waterfowl, primarily ducks and geese, in the North American continent use the Pacific Flyway (for nesting or migrating through the Central Valley), attempts are being made to restore suitable habitat and refuges by government and private organizations for both migrating and resident (2-3% of total) birds.

One of only six wildlife refuge units operated by the California Department of Fish and Game was selected as a study area. The 3,200-acre Los Banos Wildlife Area, Fig. V-13, practices a multiobjective refuge management that not only provides for waterfowl hunting in winter, but also for other types of hunting, fishing, camping and picnicking, along with various kinds of nature study.

The single most important operational activity in this refuge, in terms of management, is the manipulation of water. Proper water management is necessary to establish and maintain both wetland and upland habitats for the above recreational uses. The Los Banos Wildlife Area has 80,000 lineal feet of supply and drain ditches, and 400 acres of permanent (impounded) water. About 2,400 acres of marshland are annually ponded for waterfowl and other marsh-associated wildlife, starting in June with optimum water levels attained by mid-October. These ponds are kept flooded until late April. In addition, irrigation is required for vegetation in upland areas that provide food and cover for mammals and birds.

FIG. V-13

LOS BANOS WILDLIFE AREA


N
MUD SLOUGH
Little Buttonwillow Lake
LBWA-9
Big Buttonwillow Lake
38
LBWA-14
37
HORSESHOE POND
City Drain
LBWA-10
LBWA-8
West Delta Canal
OLSON POND
Ruth Lake Lowlift
LBWA-12
LBWA-11
Boundary
RUTH LAKES
San Luis Canal
11
BEAVER POND
Drain
LBWA-7
Lowlift No. 2
LBWA-6
LBWA-13
Flume
LBWA-5
San Pedro Canal
MUD SLOUGH
LBWA-2
HQ
LBWA-3
LBWA-4
LBWA-1
HENRY MILLER AVE
● SAMPLING STATIONS
IMPROVED DIRT ROAD
ADMINISTRATIVE ROAD
LAKES, PONDS AND SLOUGHS

Fourteen sampling stations were monitored in and around the Los Banos Wildlife Area, which are described in Appendix Table 30 and shown on the map in Fig. V-13. Monthly water flow, where available, and water quality data are reported in Appendix Table 31. Station LBWA-1 is the San Luis Federal Drain for the U.S. Bureau of Reclamation's San Luis Project, west of our study area. This drain conveys tile effluents only, and terminates at the Kesterson Reservoir, east of Gustine. The water in the San Luis Federal Drain is not reused, and our sampling of the drain was only carried out to compare the irrigation return flow containing tile effluents only (San Luis Drain) with that containing a mixture of collected surface irrigation return flow in our study area, part of which may have been reused more than once in the Mendota-Crows Landing Return Flow Group. The wildlife area obtains part of its supply water from the San Luis Canal (LBWA-2 and LBWA-11), which is not to be confused with the San Luis Federal Drain (LBWA-1). Attempts were made to get flow estimates for each of the 13 stations in the Los Banos Wildlife Area, but were successful at only six stations.

Tables V-16 and V-17 present a summary of the water quality data for the major inflows and outflows and internal stations in the Ruth Lake complex as well as the San Luis Federal Drain for comparison purposes. Based on available estimates on inflows to the refuge, LBWA-5 is the major supply water for the period April through October, 1976. Mud Slough is known to convey substantial flows, but what portion of it is utilized is unknown, since an estimate on water lifted for Ruth Lake (LBWA-12) was not possible to obtain and attempts to measure flow into (LBWA-4) was also not successful. The flow out of Mud Slough (LBWA-10) was measured with a current meter. The costs of installing additional water flow measuring devices and structures, other than staff gages and current velocity measurements, were too prohibitive for this project.

Table V-16: Summary of Water Quality Data in the Los Banos Wildlife Area from April through October 1976.

Station	Description	Q (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
LBWA-1*	San Luis Federal Drain	--	3,720	2,624	10	34	5.33	8.4
Inflow to Wildlife Area:								
LBWA-2†	San Luis Canal	1,148	2,604	1,741	77	126	3.55	8.2
LBWA-3	Municipal Sewage Effluent	11	3,292	2,205	8	15	2.76	8.0
LBWA-4	Mud Slough Inlet	--	3,379	2,267	50	82	4.13	8.3
LBWA-5‡	Boundary Drain	19,029	1,283	736	58	128	0.36	7.9
LBWA-6	San Pedro Canal	3,671	737	419	109	195	0.23	8.1
LBWA-8	West Delta Canal	2,333	1,083	600	44	112	0.35	8.1
Outflow from Wildlife Area:								
LBWA-10	Mud Slough Outlet	12,550	1,437	829	61	151	0.50	8.0
LBWA-14	Field 37 and 38 Discharge	--	2,411	1,392	31	409	0.89	8.2
LBWA-9	Buttonwillow Lake Outflow	--	1,672	957	44	49	0.50	8.4
Internal Stations**:								
LBWA-12	Ruth Lake Low Lift Pump	--	1,906	1,166	43	68	1.10	8.5
LBWA-13	Ruth Lake Discharge	--	2,253	1,356	33	41	1.47	8.3

* not used in wildlife area

† LBWA-11 same as LBWA-2, flow is sum of the two

‡ LBWA-7 same as LBWA-5

** also LBWA-11 and LBWA-2

Table V-17: Summary of Nitrogen and Oxygen Demand Parameters in the Los Banos Wildlife Area from April through October 1976.

Station	Description	Total N	Organic-N	NH_4-N	NO_3-N	NO_2-N	BOD	DO
		←		mg per liter				→
LBWA-1*	San Luis Federal Drain	1.59	1.36	0.13	0.10	0.01	3.0	9.51
Inflow to Wildlife Area:								
LBWA-2†	San Luis Canal	8.33	1.12	0.15	6.96	0.11	2.6	9.62
LBWA-3	Municipal Sewage Effluent	7.74	4.59	2.95	0.12	0.02	5.5	9.63
LBWA-4	Mud Slough Inlet	2.54	2.25	0.22	0.08	0.01	4.8	9.43
LBWA-5‡	Boundary Drain	2.41	1.14	0.45	0.76	0.06	3.1	9.65
LBWA-6	San Pedro Canal	1.80	0.92	0.07	0.79	0.02	1.1	9.24
LBWA-8	West Delta Canal	1.93	0.96	0.13	0.79	0.04	3.2	9.55
Outflow from Wildlife Area:								
LBWA-10	Mud Slough Outlet	2.67	1.52	0.37	0.72	0.06	3.2	9.46
LBWA-14	Field 37 and 38 Discharge	4.05	3.61	0.37	0.07	0.01	8.16	9.44
LBWA-9	Buttonwillow Lake Outflow	2.63	2.57	0.05	0.01	0.01	5.0	9.85
Internal Stations**:								
LBWA-12	Ruth Lake Low Lift Pump	3.05	2.61	0.19	0.14	0.11	9.0	9.42
LBWA-13	Ruth Lake Discharge	5.36	5.17	0.09	0.11	0.01	10.4	9.30

* not used in wildlife area

† LBWA-11 same as LBWA-2

‡ LBWA-7 same as LBWA-5

** also LBWA-11 and LBWA-2

An examination of the quality of inflow water shows two types of water; namely, moderately saline-high boron waters from LBWA-2, LBWA-3, and LBWA-4, and less saline-low boron waters from LBWA-5, LBWA-6, and LBWA-8. The latter group of waters represent more the quality of freshwater found in the Delta-Mendota Canal, while the former is typical of irrigation return flow and reused return flow in this area. The San Luis Federal Drain (LBWA-1), in comparison, is more saline, higher in boron, and lower in suspended matter. This is expected, since the drain conveys tile effluents only. The quality of the tile drainage is such that it has limited beneficial uses.

Three outflow stations were sampled in this study area. LBWA-10 is a downstream station in Mud Slough above the outfall of the Los Banos City Drain. Comparing the inlet (LBWA-4) and the outlet (LBWA-10) of Mud Slough, it is noted that salinity and boron are lower at the outlet than in the inlet, while suspended matter is higher. Complicating this comparison are other sources of excess supply water which may eventually discharge into Mud Slough, namely, San Luis Canal (LBWA-2, LBWA-11) and Boundary Drain (LBWA-5). The former is saline while the latter is less saline. Outflow Station LBWA-14 is for the discharge of water into Mud Slough from Fields 37 and 38, and others, that receive much of their supply water from Boundary Drain (LBWA-5) and Mud Slough (LBWA-4). A substantial increase in suspended load is noted when compared to LBWA-5 and LBWA-4. This is due to the large amounts of water discharged into the Mud Slough during the months of May and June. LBWA-9 is a discharge station for Buttonwillow Lake, which receives much of its supply water from the West Delta Canal (LBWA-8). In our monthly sampling this station was flowing for four months, in contrast to last year when it was flowing only in June. The quality of LBWA-9 is similar to that of LBWA-8, except for a slight increase in salinity and decrease in suspended solids, which was expected due to evaporation losses from the lake surface and settling of sediments.

The Upper and Lower Ruth Lakes receive their supply water from Mud Slough at LBWA-12 and San Luis Canal at LBWA-11, and between LBWA-11 and LBWA-2. Mud Slough and San Luis Canal contain moderately saline, turbid, high-boron waters. LBWA-12, Ruth Lake low lift pump, had lower levels of salinity, suspended matter and boron than Mud Slough and the discharge water, LBWA-13, had a similar salinity level as the San Luis Canal, but was lower in suspended matter and boron. With regards to these quality parameters, the major change appears to be a reduction in the sediment load by impoundment of waters in the Ruth Lake complex. The pH value for all the waters in the area ranged from 7.9 to 8.5.

Table V-17 presents a summary of the different nitrogen species, dissolved oxygen (DO), and biochemical oxygen demand (BOD) in the waters of the Los Banos Wildlife Area. As pointed out from data presented in Table V-16, San Pedro Canal, Boundary Drain, and West Delta Canal were low in boron and salinity as compared to San Luis Canal, Mud Slough, and the sewage effluent. For these inflow waters, the San Luis Canal (LBWA-2) and the sewage effluent (LBWA-3) contained the highest Total N, while LBWA-3 contained the highest levels of organic-N, NH_4-N, and BOD. The DO levels were almost the same in all these waters. San Luis Canal had the highest amount of NO_3-N, yet all other parameters were similar to other inflows (except LBWA-3). The range of Total N between 1.5 to 2.4, primarily in the organic-N and NO_3-N forms, is typical of irrigation return flows. With the exception of Mud Slough and Municipal Sewage Effluent, the BOD were also typical of irrigation return flows. The exceptions were probably higher due to animal and plant residues.

With regards to outflow, the most noticeable change in the distribution of various N species was the slight increase in organic-N and the concurrent reduction in NO_3-N. A similar finding is noticed in the internal stations for the Ruth Lake complex. BOD in LBWA-13 was significantly higher, due primarily to the decay of marshland type vegetation in stagnant to slow-moving water; however, DO was the same as other stations. It appears that a substantial reduction in Total N, in particular NO_3-N, occurred in Ruth Lake when compared to San Luis Canal, the canal being a major source of water for this lake complex. This reduction is attributed to N uptake by algae and by marshland vegetation. In addition, NO_3-N was probably reduced through denitrification losses.

Tables V-18 and V-19 show similar types of data for the November through March nonirrigation seasons of 1975-76 and 1976-77. As compared to irrigation season, the major difference noted is reduction in water flow which, with some exceptions, appears to contribute to increases in salinity and decreases in suspended matter, increases in NO_3-N in inflow stations and decreases in NO_3-N outflow and internal stations, and decreases in BOD.

In summary, the Los Banos Wildlife Area contributes to the abatement of pollution by reusing irrigation return flows from croplands and pasturelands, and reducing the sediment and NO_3-N loads in these return flows. Although organic-N tends to increase, it is not a major pollutional hazard as NO_3-N or NH_4-N because organic-N may not become completely mineralized at downstream location, or in receiving waters. Similar conclusions may be reached for other water reuse areas such as the grasslands.

Table V-18: Summary of Water Quality Data in the Los Banos Wildlife Area

November through March, 1975-76 and 1976-77 (i.e., two non-irrigation seasons only)

Station	Description	Q[1/] (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
LBWA-1*	San Luis Federal Drain	-	4,749	3,554	10	30	6.73	8.3
Inflow to Wildlife Area:								
LBWA-2†	San Luis Canal	670	3,430	2,391	32	51	4.59	8.3
LBWA-3	Municipal Sewage Effluent	34	2,862	1,819	22	28	2.53	8.0
LBWA-4	Mud Slough Inlet	-	2,671	1,792	25	40	2.83	8.6
LBWA-5‡	Boundary Drain	18,789	2,130	1,256	29	52	0.91	8.2
LBWA-6	San Pedro Canal	2,059	978	568	27	38	0.34	8.4
LBWA-8	West Delta Canal	1,415	1,425	843	22	36	0.45	8.1
Outflow from Wildlife Area:								
LBWA-10	Mud Slough Outlet	9,654	2,376	1,655	32	56	1.97	8.2
LBWA-14	Field 37 and 38 Discharge	-	2,371	1,396	11	15	1.16	8.3
LBWA-9	Buttonwillow Lake Outflow	-	1,473	858	17	107	0.37	8.4
Internal Stations**:								
LBWA-12	Ruth Lake Low Lift Pump	-	2,155	1,334	29	31	1.28	8.6
LBWA-13	Ruth Lake Discharge	-	2,661	1,736	12	19	1.95	8.3

[1/] Q represents total flow (measured and/or estimated) for the two non-irrigation seasons

* not used in the wildlife area

** also LBWA-11 and LBWA-2

† LBWA-11 same as LBWA-2, flow is sum of the two

‡ LBWA-7 same as LBWA-5

Table V-19: Summary of Nitrogen and Oxygen Demand Parameters in the Los Banos Wildlife Area

November through March, 1975-76 and 1976-77 (i.e., two non-irrigation seasons only)

Station	Description	Total N	Organic-N	NH_4-N	NO_3-N	NO_2-N	BOD	DO
		← mg per liter						→
LBWA-1*	San Luis Federal Drain	2.98	1.28	0.32	1.31	0.07	1.74	9.74
Inflow to Wildlife Area:								
LBWA-2†	San Luis Canal	9.01	1.20	0.17	7.52	0.11	1.10	9.82
LBWA-3	Municipal Sewage Effluent	20.69	13.39	6.97	0.31	0.04	8.40	10.14
LBWA-4	Mud Slough Inlet	3.81	1.53	0.33	1.68	0.04	2.13	9.93
LBWA-5‡	Boundary Drain	2.42	0.95	0.26	1.16	0.05	2.93	10.13
LBWA-6	San Pedro Canal	1.27	0.75	0.07	0.44	0.00	1.40	10.52
LBWA-8	West Delta Canal	2.48	0.61	0.41	1.55	0.06	0.94	9.81
Outflow from Wildlife Area:								
LBWA-10	Mud Slough Outlet	3.06	1.26	0.35	1.41	0.04	2.25	9.70
LBWA-14	Field 37 and 38 Discharge	1.38	1.42	0.35	0.09	0.02	2.91	9.61
LBWA-9	Buttonwillow Lake Outflow	1.98	1.50	0.29	0.17	0.02	2.57	10.17
Internal Stations**:								
LBWA-12	Ruth Lake Low Lift Pump	2.16	1.99	0.14	0.02	0.01	5.00	8.88
LBWA-13	Ruth Lake Discharge	1.82	1.46	0.30	0.05	0.01	3.60	9.84

* not used in wildlife area

** also LBWA-11 and LBWA-2

† LBWA-11 same as LBWA-2

‡ LBWA-7 same as LBWA-5

CHAPTER VI. SACRAMENTO VALLEY FIELD STUDIES

A. Sacramento Valley Return Flow Group.

The Sacramento Valley Water Quality Committee has received an NPDES permit to discharge irrigation return flows in the Sacramento River System. This return flow group has more than 47 cosigners who belong to either the Sacramento Valley Water Quality Committee or the California Central Valley's Flood Control Association. These cosigners include 14 irrigation and water districts, 20 reclamation districts, 5 drainage districts, and 8 individual landowners.

The Sacramento Valley Return Flow Group's boundaries extend over an area of one million acres of irrigated lands (Fig. VI-1) from as far north as Hamilton City to as far south as Sacramento. The Group discharges irrigation and other return flows into the Sacramento and Feather Rivers through 13 major drains. The NPDES permit requires monthly monitoring of Q, EC, and SS from 16 NPDES discharge points, as well as quarterly monitoring of two supply points located on the Sacramento River at Hamilton City and on the Feather River at Thermalito. Unlike the Mendota-Crows Landing Return Flow Group which has a self-monitoring program and determines their own water quality data, the Sacramento Return Flow Group has contracted out the monitoring and quality analyses to the California Department of Water Resources.

Because of the extensive nature and large number of discharge points within the Sacramento Group, the Glenn-Colusa Irrigation District (GCID) and the Colusa Basin Drain (CBD) were selected for field studies in this project. GCID (Fig. VI-2) is a typical district in the valley, with flooded rice culture as the major crop. Within this district, four rice fields were monitored in 1976. GCID receives its supply water primarily by diverting water from the Sacramento River, near Hamilton City (S-1), and discharges its

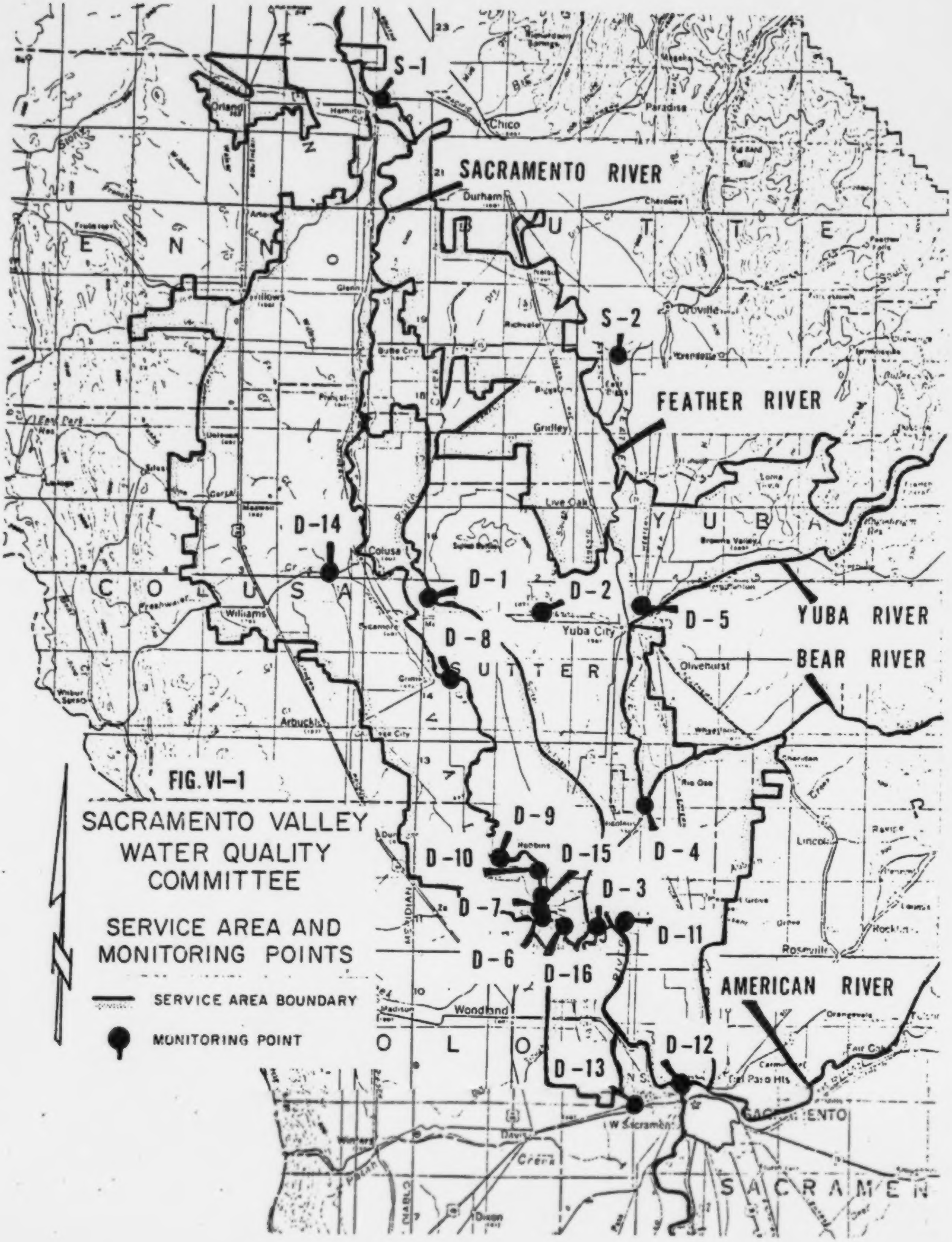

S-1
SACRAMENTO RIVER
S-2
FEATHER RIVER
D-14
D-1
D-2
D-5
YUBA RIVER
BEAR RIVER
D-8
D-9
D-10
D-15
D-4
D-3
D-7
D-11
D-6
D-16
AMERICAN RIVER
D-12
D-13
G L E N N
B U T T E
Y U B A
C O L U S A
S U T T E R
Y O L O
S A C R A M E N
Orland
Hamilton
Chico
Paradise
Durham
Oroville
Willows
Glenn
Butte City
Biggs
Gridley
Live Oak
Colusa
Williams
Yuba City
Olivehurst
Wheatland
Arbuckle
Grimes
Robbins
Lincoln
Roseville
Rocklin
Woodland
Davis
Winters
Dixon
W Sacramento
SACRAMENTO
Orangevale
Fair Oaks
Del Paso Hts
SERVICE AREA BOUNDARY
MONITORING POINT

FIG. VI–1

SACRAMENTO VALLEY WATER QUALITY COMMITTEE

SERVICE AREA AND MONITORING POINTS

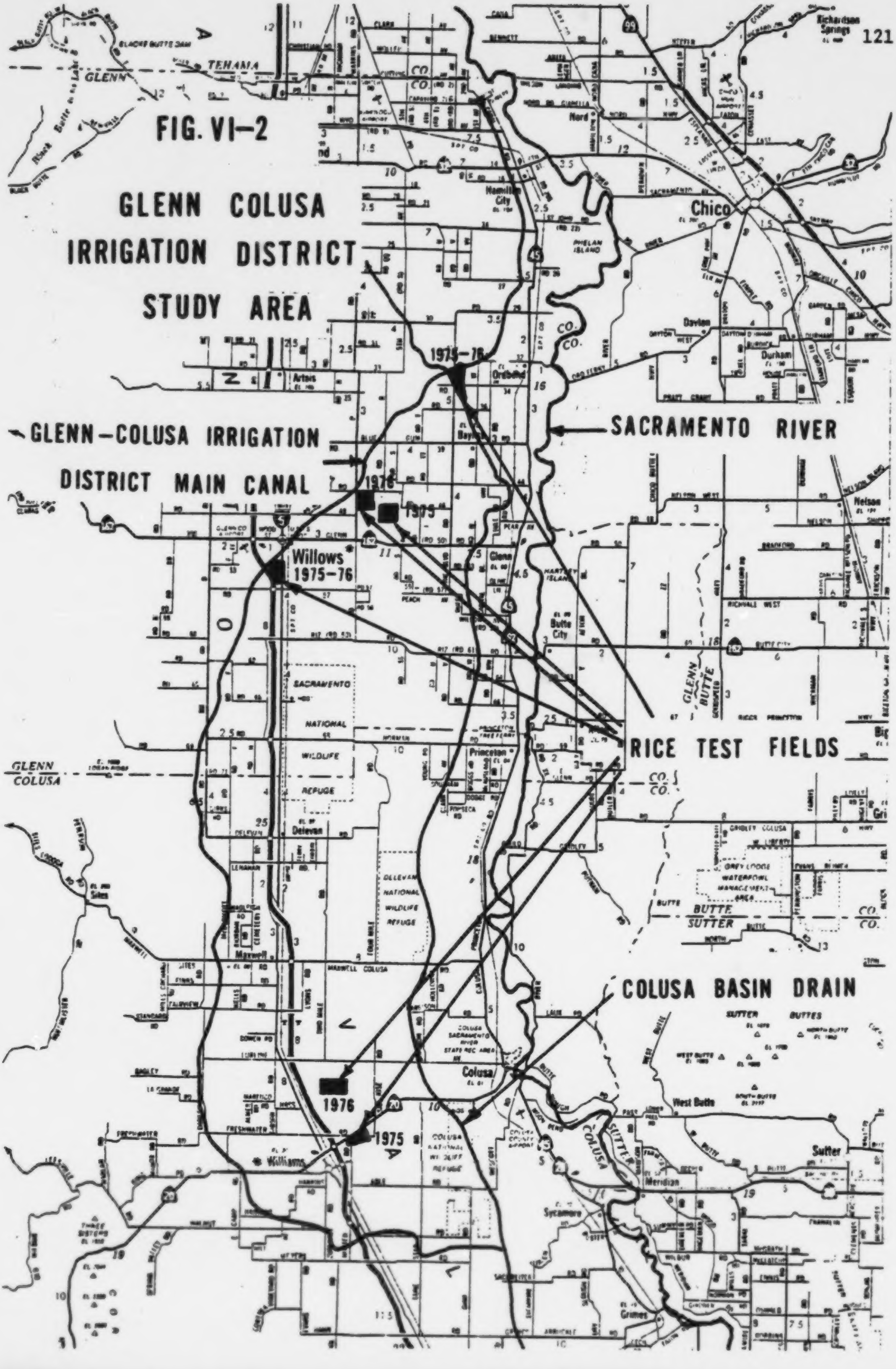


FIG. VI-2

GLENN COLUSA IRRIGATION DISTRICT STUDY AREA

GLENN-COLUSA IRRIGATION DISTRICT MAIN CANAL
SACRAMENTO RIVER
RICE TEST FIELDS
COLUSA BASIN DRAIN
1975-76
1976
1305
Willows 1975-76
1976
1975
TEHAMA
GLENN
COLUSA
BUTTE
SUTTER
Richardson Springs
Chico
Nord
Hamilton City
Phelan Island
Dayton
Durham
Ord Bend
Artois
Bayliss
Glenn
Nelson
Butte City
Princeton
Delevan
Maxwell
Colusa
Williams
Sites
Meridian
Sutter
West Butte
Sycamore
Grimes
SACRAMENTO NATIONAL WILDLIFE REFUGE
DELEVAN NATIONAL WILDLIFE REFUGE
COLUSA NATIONAL WILDLIFE REFUGE
GRAY LODGE WATERFOWL MANAGEMENT AREA
SUTTER BUTTES
CO.
CO.

return flow into CBD (Fig. VI-3). The NPDES permit includes three stations on the Colusa Basin Drain (Fig. VI-1); D-14, at the crossing with Highway 20; D-6, at the Colusa Basin Drain outfall into the Sacramento River above Knights Landing; and D-7, Reclamation District 787's drain near the confluence with CBD. This EPA project is also monitoring water quality at station D-14 (CBD-3 in Fig. VI-3), and at a station upstream from D-6 and D-7 (CBD-1 in Fig. VI-3).

B. Glenn-Colusa Irrigation District.

The 163,700 acre Glenn-Colusa Irrigation District (GCID) is located on the west side of the Sacramento Valley (Fig. VI-2). In the 1976 irrigation season, 866,000 ac-ft of water (Table VI-1) was delivered to 140,234 acres of crop and refuge lands (Appendix Table 32), 58% of which were devoted to rice production. In 1976, total irrigated acreage increased from 132,436 acres in 1975, but rice acreage decreased from 94,076 acres in 1975 to 82,047 in 1976. Supply waters diverted from the Sacramento River and from Stony Creek, D-14 in Fig. VI-4, are conveyed by a main canal that runs along the district's western boundary, more or less parallel to Highway Interstate 5.

GCID practices reuse of its irrigation return flows with either gravity diversions or drain pumps. Table VI-1 indicates 214,700 ac-ft, or 25% of the diverted water, was captured and reused in 1976. Lateral spills were about 2% of the total diversions, or 13,900 ac-ft. The surface return flows from GCID were estimated to be 183,800 ac-ft, or 21% of the total diversions. GCID's irrigation return flows are conveyed by 11 lateral drains (Fig. VI-4) to the upper reaches of the Colusa Basin Drainage Canal. Monthly drain outflows for the 11 lateral drains are tabulated in Appendix Table 33, which shows a decrease of 60,000 ac-ft from last year.

Table VI-2 presents the seasonal flow-weighted average quality of GCID's supply water, its 11 lateral drains, and a calculated overall district drain

FIG. VI-3

COLUSA BASIN DRAIN

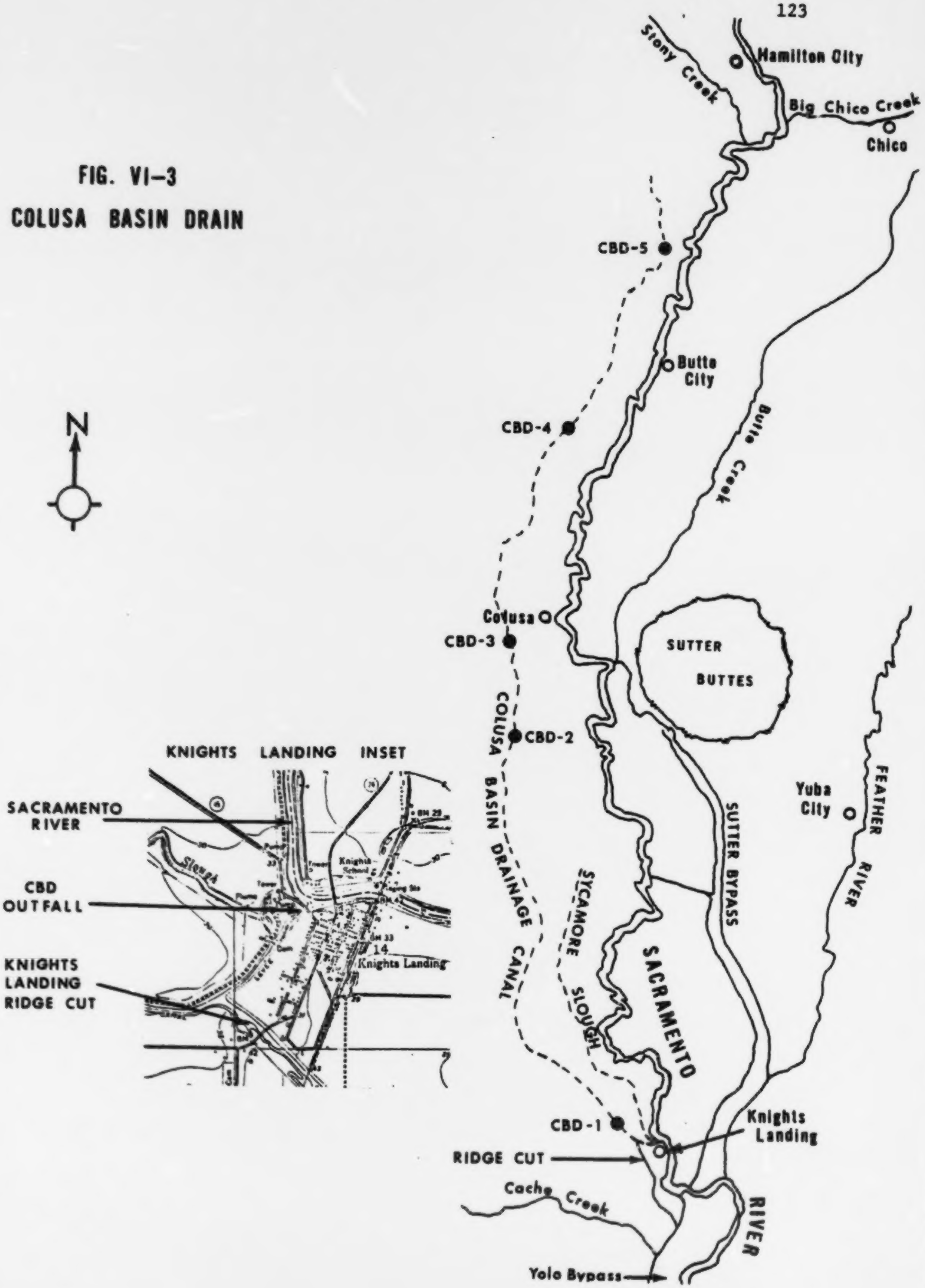

Stony Creek
Hamilton City
Big Chico Creek
Chico
CBD-5
Butte City
CBD-4
Butte Creek
Colusa
CBD-3
SUTTER BUTTES
CBD-2
COLUSA BASIN DRAINAGE CANAL
SYCAMORE SLOUGH
SACRAMENTO
SUTTER BYPASS
Yuba City
FEATHER RIVER
CBD-1
Knights Landing
RIDGE CUT
Cache Creek
RIVER
Yolo Bypass
N
KNIGHTS LANDING INSET
SACRAMENTO RIVER
CBD OUTFALL
KNIGHTS LANDING RIDGE CUT
Slough
Knights School
14
Knights Landing

Table VI-1: Summary of Monthly Water Flows in Acre-Feet in Glenn-Colusa Irrigation District During the 1976 Irrigation Season.

Description	April	May	June	July	August	September	October	Total
Supply Water:								
Sacramento River Diversion	115,900	154,200	163,700	161,300	140,400	66,600	33,200	835,300
Stony Creek Diversion	11,300	12,400	200	6,800	0	0	0	30,700
Total Diversion	127,200	166,600	163,900	168,100	140,400	66,600	33,200	866,000
Drain Recapture:								
Drain Pumps	8,800	26,500	27,300	32,200	31,400	11,400	700	138,300
Gravity Diversions	10,300	13,400	14,900	16,200	15,400	4,900	1,300	76,400
Total Recapture	19,100	39,900	42,200	48,400	46,800	16,300	2,000	214,700
Lateral Spills:	2,700	1,500	1,100	1,100	1,400	3,000	3,100	13,900
Drain Outflow:	20,600	37,400	19,100	18,900	36,700	38,500	12,600	183,800

FIGURE VI–4

GLENN-COLUSA IRRIGATION DISTRICT

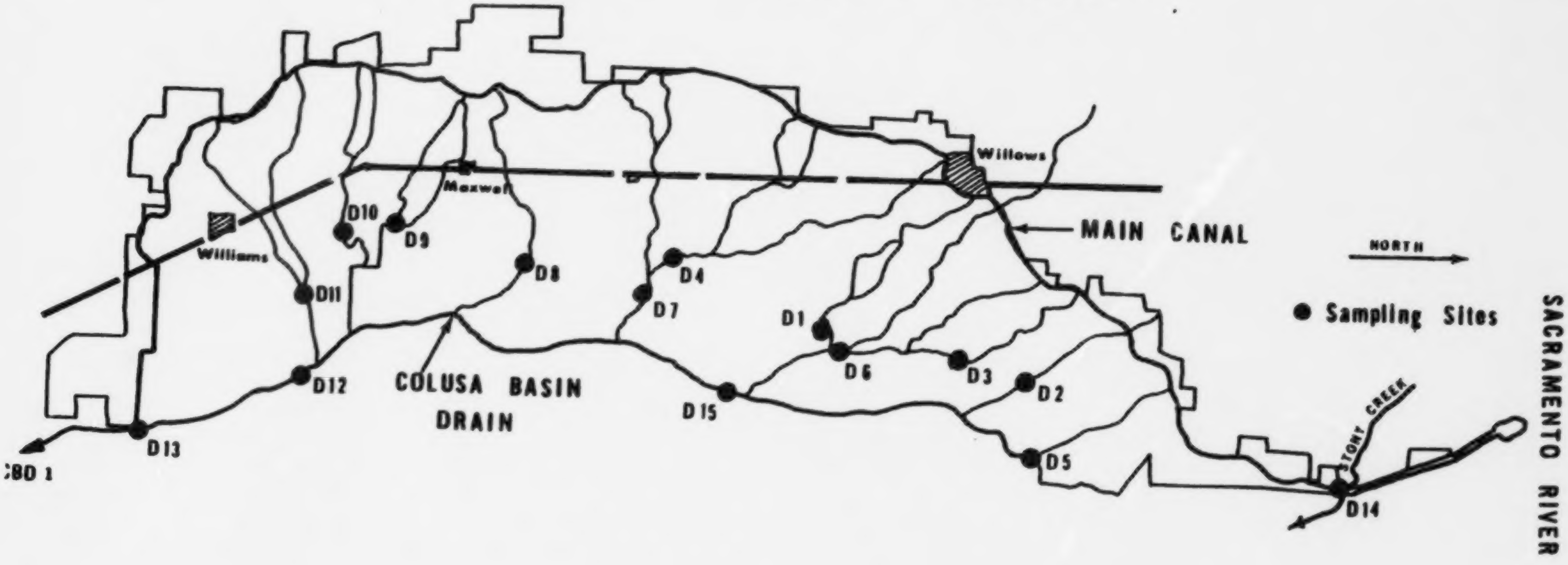

Willows
MAIN CANAL
NORTH
● Sampling Sites
SACRAMENTO RIVER
STONY CREEK
Maxwell
Williams
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
COLUSA BASIN DRAIN
CBD 1

Table VI-2: Flow-Weighted Average Water Quality in the 1976 Irrigation Season (April through October) for Glenn-Colusa Irrigation District

Description		Seasonal Flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Supply Water:						
	D-14	824,400	133	97	8	12
Lateral Drains*:						
GCID 2047 @ Sidds Rd.	D-5	11,800	322	197	21	48
GCID Bondurant	D-2	2,100	271	177	18	29
GCID Drain 55	D-3	31,900	301	185	9	13
Willow Creek	D-6	15,700	341	210	13	18
Salmon Hole	D-1	2,300	313	201	17	22
Logan Creek	D-4	5,500	591	374	29	50
Hunter Creek	D-7	10,400	339	200	21	35
Stone Corral	D-8	24,900	411	249	14	59
Kuhl Weir	D-9	13,100	358	221	29	46
Section 25	D-10	12,700	351	216	55	102
Freshwater Creek	D-11	16,600	639	389	73	121
District Drain Outflow*:						
		147,000	386	237	26	50

* based on measured monthly flows

outflow. The monthly quality and flow data are reported in Appendix Tables 34, 35, and 36. GCID's supply water is of extremely high quality, while its surface return flow is nearly the same seasonal quality as that of the supply water for the Mendota-Crows Landing Return Flow Group (see Table V-1).

Appendix Tables 37 and 38 give the relation between TDS and EC, and SS and turbidity. Except for D-6, D-9, and D-10, TDS is highly correlated to EC. The r-values for the turbidity vs. SS relationship in these stations were, in general, not as high as the salinity parameters; however, good correlations were obtained for most of them.

Tables VI-3 and VI-4 give the nonirrigation season water flows and flow-weighted average quality for 1975-76 and 1976-77, respectively. Note that the salinity (EC and TDS) and suspended matter (Turbidity and SS) parameters are in general all higher during nonirrigation vs. irrigation season. The flows in the winter of 1975-76 and 1976-77 were unusually low due to drought conditions.

Table VI-5 analyzes water, salt, and sediment flows in GCID. When compared to Panoche Drainage District (Table V-9), GCID has a slightly lower surface drainage index (0.21 vs. 0.31), but a higher unit applied water (6.18 vs. 3.58 ft) and a higher unit surface drainage (1.31 vs. 0.95 ft). These differences may be attributed to the predominance of flooded rice culture in GCID, as compared to field and row crops in Panoche Drainage District, and to the greater reuse of drain waters in GCID (25%) compared to Panoche Water District (3.6%).

It is of interest to note that the salt balance index, defined as the ratio of the salt load in the surface return flow to that of the supply water, is less than unity, i.e., 0.52. Indices less than unity are indicative of salt accumulation in the soil as soluble and insoluble salts and/or salts

Table VI-3: Flow-Weighted Average Water Quality in the 1975-1976 Non-Irrigation Season (November through March) for Glenn-Colusa Irrigation District

Description	Seasonal flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Lateral Drains*:					
GCID 2047 at Sidds Rd.	3,304	474	285	44	67
GCID Bondurant	2,519	291	183	14	20
GCID Drain 55	3,471	429	267	20	32
Willow Creek	6,070	353	205	46	66
Salmon Hole	1,341	349	218	67	108
Logan Creek	5,486	840	529	25	38
Hunter Creek	2,947	872	508	32	58
Stone Corral	5,813	607	354	32	70
Kuhl Weir	2,116	647	344	40	67
Section 25	2,845	567	329	23	13
Freshwater Creek	2,480	808	474	29	39
District Drain Outflow*:	38,392	575	343	33	52

*Based on estimated monthly flows.

Table VI-4: Flow-Weighted Average Water Quality in the 1976-1977 Non-Irrigation Season (November through March) for Glenn-Colusa Irrigation District

Description	Seasonal flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
Lateral Drains*:						
GCID 2047 at Sidds Rd.	2,072	340	198	109	102	7.8
GCID Bondurant	1,717	335	196	528	407	7.3
GCID Drain 55	3,189	298	181	1,412	822	7.6
Willow Creek	2,042	332	200	91	60	8.0
Salmon Hole	421	528	309	14	20	8.1
Logan Creek	4,856	882	543	39	53	7.9
Hunter Creek	2,898	699	443	158	173	8.1
Stone Corral	7,208	770	405	1,553	1,942	7.9
Kuhl Weir	4,516	819	455	247	248	8.1
Section 25	2,259	612	346	236	190	8.3
Freshwater Creek	2,900	824	500	58	85	7.9
District Drain Outflow*:	34,078	652	381	572	593	7.9

*Based on estimated monthly flows.

Table VI-5: Analysis of Water, Salt, and Suspended Matter
in Glenn-Colusa Irrigation District for the 1976 Irrigation Season

Unit Applied Water = supply/irrig. acres = 866,000/140,200 = 6.18 ac-ft/ac

Unit Surface Drainage = surface discharge/irrig. acres = 183,800/140,200 = 1.31 ac-ft/ac

Surface Drainage Index = surface discharge/supply = 0.21

Salt (TDS) Input = 114,243 tons or 1,630 lbs/ac

Salt Output = 59,242 tons or 724 lbs/ac

Salt Balance Index = output/input = 0.52

Sediment (SS) Input = 14,133 tons or 202 lbs/ac

Sediment Output = 12,498 tons or 153 lbs/ac

Sediment Balance Index = output/input = 0.88

leached in percolating waters not collected by the drains. A similar analysis made on sediments gives an index of only 0.88. Apparently, much of the suspended matter in the supply water settles out in the rice fields and/or in the distribution-drainage systems. Although SS in Glenn-Colusa Irrigation District's supply water is low (12 mg/liter) as compared to that of Broadview Water District's (55 mg/liter), the inputs of sediment are comparable, 202 and 235 lbs/ac, respectively, due to a higher unit applied water in the former.

Appendix Table 39 reports detailed quality data for the July, September, 1976, and January, 1977 water samples. As pointed out earlier, the salinity in the supply and drain waters was low. Total N ranged from 0.5 to about 5 mg/liter, predominated by Organic-N rather than the mineralized forms of NH_4-N, NO_3-N, and NO_2-N. The January 3, 1977, sample for Station D-8 had exceedingly high Organic-N concentration of 14.5 mg/liter. In fact, all of the samples taken at this date gave higher values of N species than the other two sampling dates. SS were also higher. It is of interest to note that this January sampling was carried out during a period with precipitation runoff from both within the district and the surrounding watershed after a long period of no rainfall. BOD ranged from 0.6 to 12.6 mg/liter, the higher values probably reflect both sewage effluents discharged into drains by several municipalities, and animal wastes from pastures and wildlife refuges. The pH values ranged from 7.7 to 8.6.

Rice Test Fields.

Figure VI-2 shows the general locations of four monitored rice fields, ranging from 50 to 141 acres in size. Appendix Table 40 contains the sampling locations in the rice test fields and Appendix Table 41 contains detailed information and data for these rice test fields with regards to the varieties of rice planted, dates of planting and harvest, and other cultural practices such as irrigation, fertilization, and weed control.

Table VI-6 gives the analyses describing water balances for the four rice fields. Inflow was measured with a Hersey-Sparling propeller type totalizing meter while outflow was measured with a 90° v-notch weir and a Leopold-Stevens water stage recorder. Evapotranspiration (ET) was estimated from Class A pan data (using a coefficient of 0.9), and seepage losses were obtained by difference. Table VI-6 gives applied water ranging from 6.2 to 10.7 ac-ft/ac, and surface outflow ranging from 0.6 to 4.5 ac-ft/ac. The percentage of spill ranged from 6 to 43%, seepage from 21 to 61%, and ET from 33 to 58% of the applied water.

Table VI-7 reports a summary of seasonal flow-weighted average quality parameters for inflow and outflow waters, based on detailed data presented in Appendix Tables 42-45. In general, the salinity in the applied water increases slightly, due to ET concentration of applied water and salt pickup from the submerged soils. As for suspended matter, except for Field 13, both turbidity and SS were lower in the surface outflow as compared to the inflow. This set of data supports the contention that rice fields act as settling basins for suspended matter. However, lateral drains (Table VI-2) in GCID have a higher suspended load. This may be attributed to the pickup of sediments in the drains, which were deposited during winter runoffs.

Figure VI-5 gives the inflow and outflow water flow rates for Fields 8 and 16, ranging from 0.01 to 0.03 cfs/ac and from 0.003 to 0.06 cfs/ac for inflow and 0.001 to 0.01 cfs/ac and nil to 0.03 cfs/ac for outflow, respectively.

Intensive monitoring studies were conducted within Fields 8 and 16 with regards to water flow patterns using a dye tracer and water quality analyses. Figure VI-6 gives the layout of test field 8 and sampling stations. During August 10-13, 1976, Rhodamine WT dye was injected in the northeast inlet (station 8-3 of Check 18). For illustrative purposes, Fig. VI-7 shows the

Table VI-6:: Water Balance Data for Rice Test Fields

Glenn-Colusa Irrigation District, 1976 Season

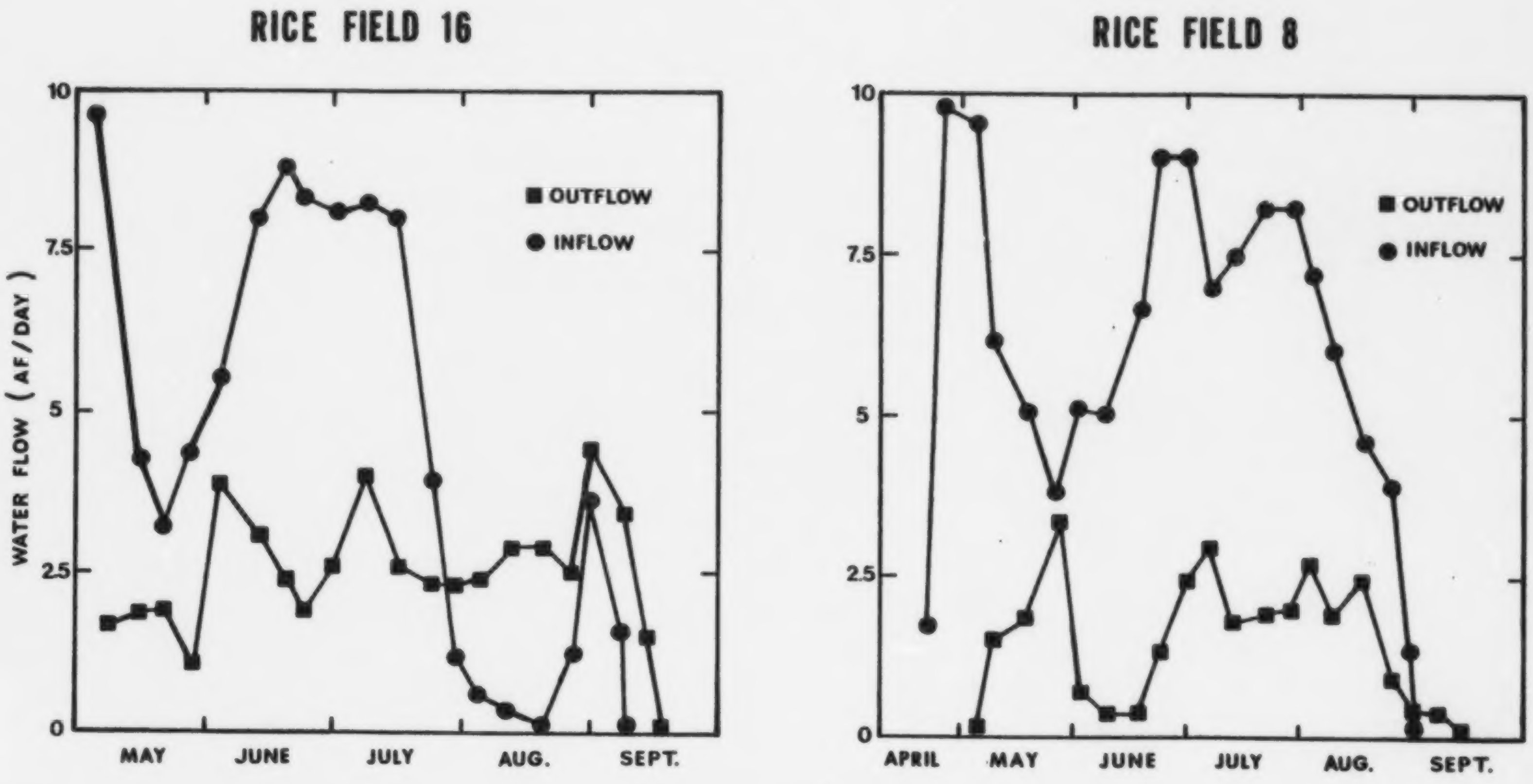
Characteristic	Field Number			
	4	8	13	16
Inflow, acre-feet/acre	10.73	6.23	8.93	10.35
Precipitation, acre-feet/acre	0.19	0.19	0.19	0.19
Total inflow, acre-feet/acre	10.92	6.42	9.12	10.54
Evapotranspiration ET, acre-feet/acre	3.69	3.59	3.75	3.43
Outflow, acre-feet/acre	0.64	1.53	.74	4.48
Seepage, acre-feet/acre[1]	6.59	1.30	4.63	2.63
(Outflow/inflow) x 100	6%	23%	8%	43%
(Seepage/inflow) x 100	61%	21%	52%	25%
(Evapotranspiration/inflow) x 100	34%	58%	42%	33%

---

[1] Presumes moisture content of soil the same at harvest as just before initial flooding.

Table VI-7: Flow-Weighted Average Water Quality in Monitored Rice Fields During the 1976 Irrigation Season

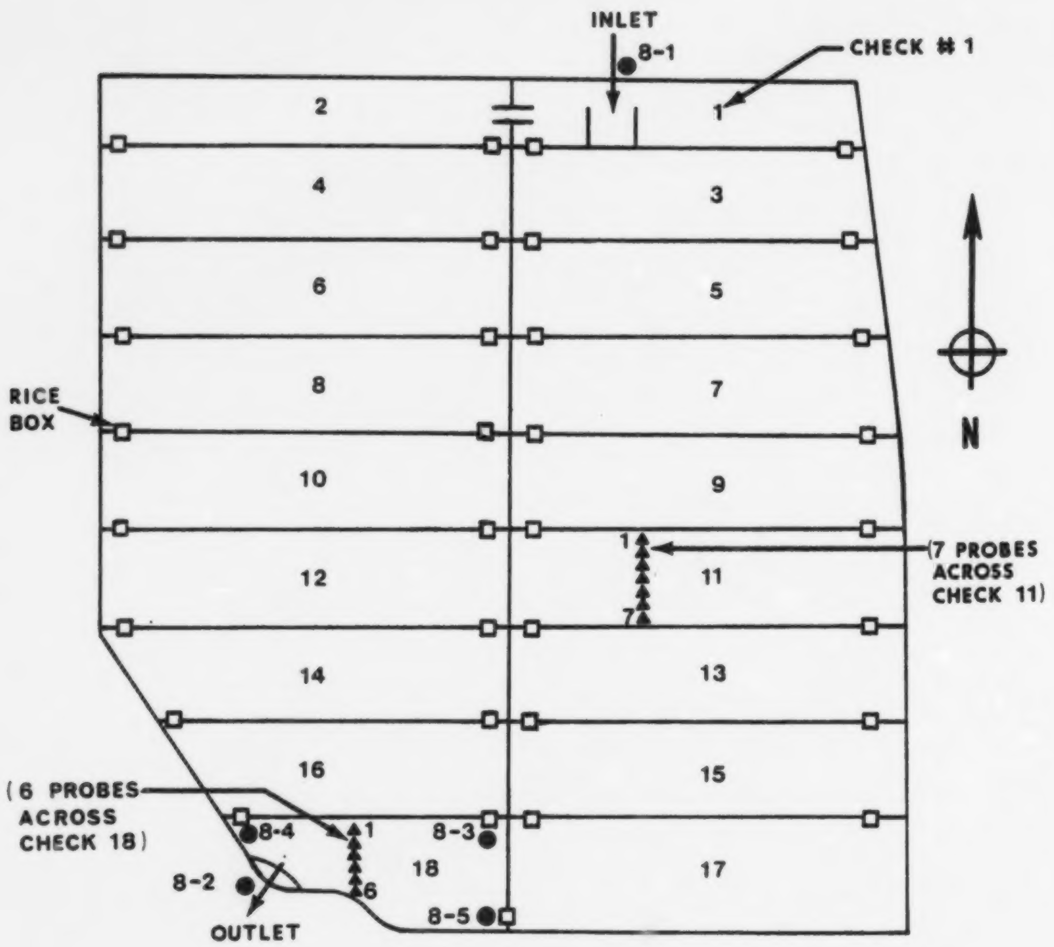
	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)
Field 4, inflow	124	92	9	13	.08
outflow	118	85	4	14	.07
Field 8, inflow	125	101	12	89	.07
outflow	182	124	9	9	.08
Field 13, inflow	133	93	7	10	.05
outflow	144	105	16	18	.06
Field 16, inflow	359	231	22	13	.38
outflow	485	296	11	10	.51
Average, all fields:					
inflow	170	121	12	34	.13
outflow	308	196	10	11	.27



RICE FIELD 16

RICE FIELD 8

FIG. VI–5 : INFLOW AND OUTFLOW RATES FOR RICE TEST FIELDS IN GLENN–COLUSA IRRIGATION DISTRICT, 1976 SEASON.


INLET
8-1
CHECK # 1
2
1
4
3
6
5
8
7
RICE BOX
10
9
N
1
(7 PROBES ACROSS CHECK 11)
12
11
7
14
13
16
15
(6 PROBES ACROSS CHECK 18)
8-4
1
8-3
8-2
18
6
17
OUTLET
8-5

● = SAMPLING STATION

1" = 500 FT.

FIG. VI—6: RICE TEST FIELD 8, GCID

SURFACE WATER PROBES AND SAMPLING STATIONS

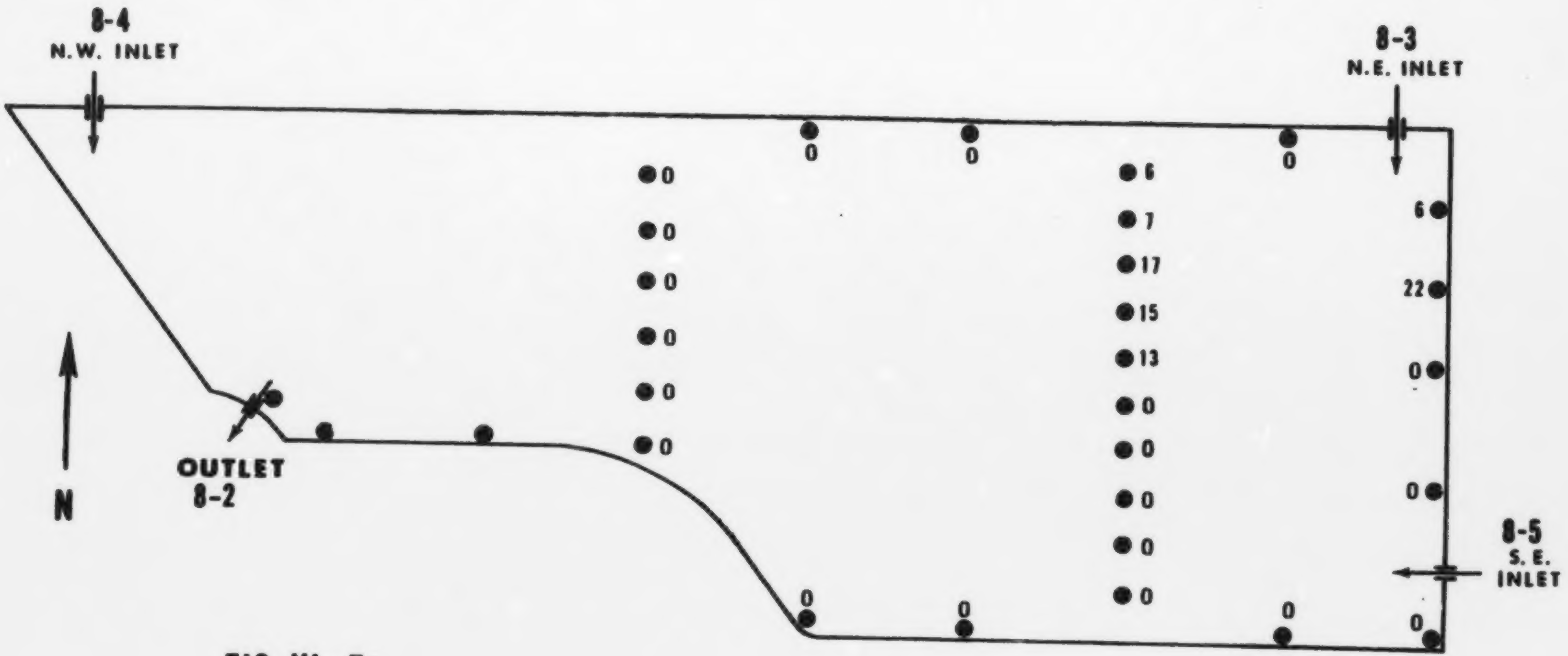

8-4
N.W. INLET
8-3
N.E. INLET
OUTLET
8-2
8-5
S.E.
INLET
N
0
0
0
0
0
0
0
0
0
0
6
7
17
15
13
0
0
0
0
0
0
0
6
22
0
0
0
0
0
0
0
● - PROBE LOCATION
N. E. INLET INJECTED
TIME : 28 HOURS
AFTER INJECTION
0
100
200
300
SCALE IN FEET

FIG. VI—7:
DYE TRACING STUDIES
RICE TEST FIELD 8
GLENN - COLUSA IRRIGATION DISTRICT
(DYE CONCENTRATIONS IN PARTS
PER BILLION)

dye concentration and distribution 28 hours after injection. The flows at inflow station 8-3 (northeast inlet) averaged 0.22 cfs at station 8-5, 0.23 cfs; at station 8-4, 0.09 cfs to nil, during the 70 hours of monitoring. Based upon such intensive dye-tracer study, the main pathway of water flow from station 8-3 to the outlet (station 8-2) is given in Fig. VI-8. Also, during August 19-20, 1976, a similar monitoring was made to trace the flow pattern for the southeast inlet (station 8-5). The flows during this monitoring period were 0.28 cfs at station 8-5; 0.36 cfs at station 8-3; and 0.09 cfs at station 8-4. Figure VI-9 gives the tracing 16 hours after injection at station 8-5 and the general water flow pattern for inlet 8-5 to outlet 8-2 is given in Fig. VI-8.

Checks 11 and 18 of Field 8 were also sampled in two week intervals over the growing season for salinity and turbidity. Figure VI-6 identifies the layout of sampling probes for surface water and Table VI-8 gives a summary of the data collected. Note that seasonal salinity of the inflow water to Field 8 at station 8-1 increased from 125 to 182 μmhos/cm while suspended solids decreased from 89 to 8.7 mg/liter in the outflow water at station 8-2. Data obtained in checks 11 and 18 support these results indicating the change in water quality as the applied water goes from one check to another.

A similar type of test was conducted within Field 16. The layout of Field 16 is given in Fig. VI-10 where intensive dye tracer studies were conducted in check 14 and water quality studies were made in checks 6 and 14 as well as the inflow and outflow. Rhodamine dye tracer was injected in the southwest inlet of check 14 on August 19, 1976, and monitored for 24 hours. The 12-hr pattern is shown in Fig. VI-11 and the main flow pattern is shown in Fig. VI-12. The inflow averaged 0.63 cfs at the southwest inlet and 0.06 cfs at the northwest inlet (Fig. VI-11) during this study. As in

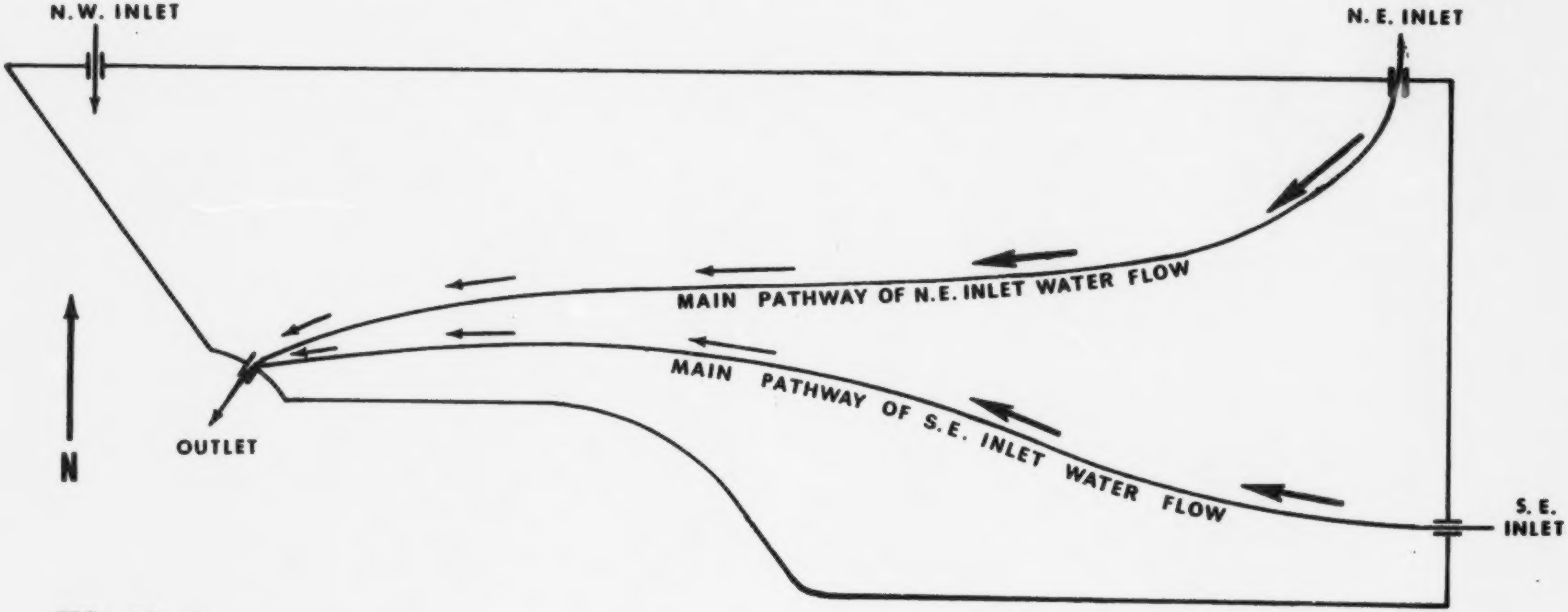

N.W. INLET
N. E. INLET
MAIN PATHWAY OF N.E. INLET WATER FLOW
MAIN PATHWAY OF S.E. INLET WATER FLOW
S. E. INLET
OUTLET
N

FIG. VI–8:
MAIN PATHWAY OF WATER MOVEMENT
DYE TRACING STUDIES – GCID
RICE TEST FIELD 8, CHECK 18
N.E. INLET AND S.E. INLET INJECTED

(LARGER ARROWS INDICATE
HIGHER DYE CONCENTRATIONS)

0
100
200
300
SCALE IN FEET

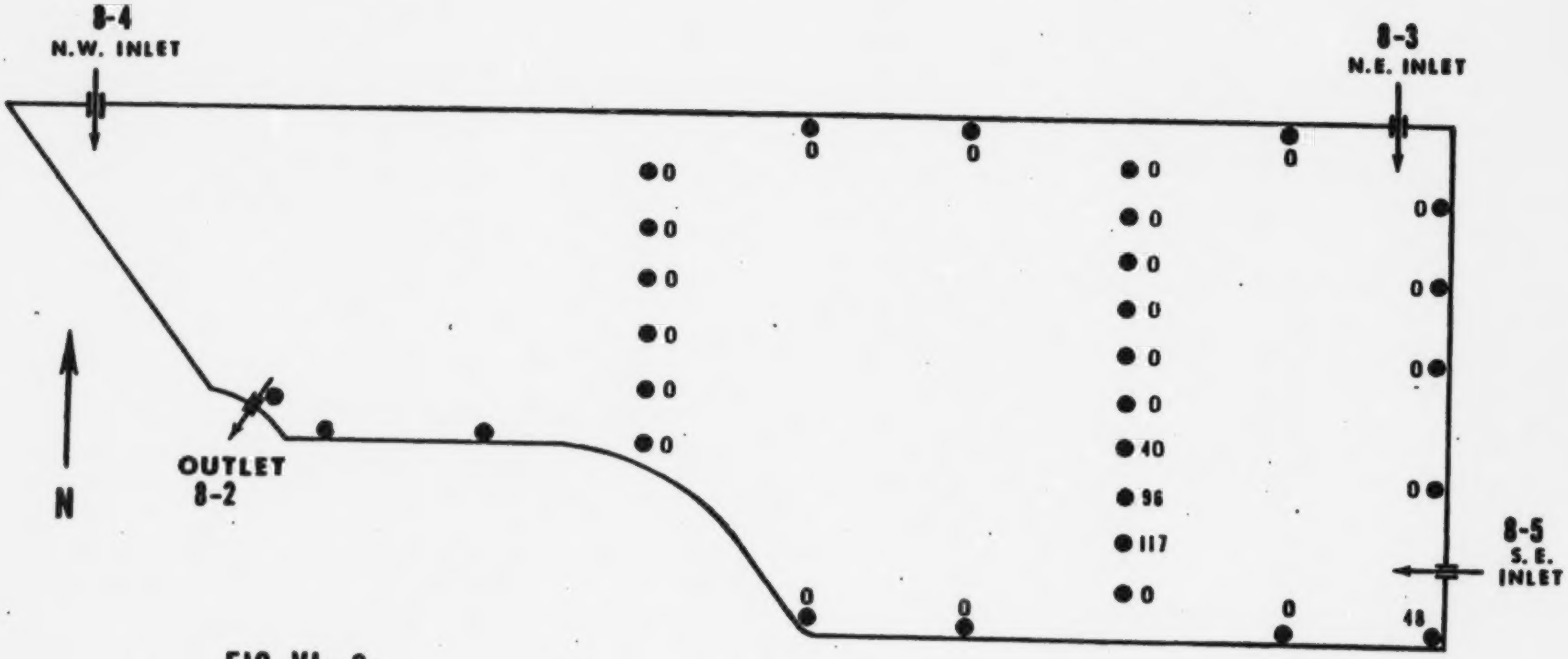

8-4
N.W. INLET
8-3
N.E. INLET
8-5
S.E. INLET
OUTLET
8-2
N
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
40
96
117
0
0
0
0
0
0
0
48

FIG. VI—9:

DYE TRACING STUDIES

RICE TEST FIELD 8

GLENN - COLUSA IRRIGATION DISTRICT

(DYE CONCENTRATIONS IN PARTS PER BILLION)

● - PROBE LOCATION

S. E. INLET INJECTED

TIME: 16 HOURS

AFTER INJECTION

0
100
200
300
SCALE IN FEET

Table VI-8: 1976 Averages - Irrigation Season

Rice Test Fields Surface Water Probes

Field #8

	EC x 10^6 (μmhos/cm)	Cl (mg/ℓ)	Turbidity (JTU)	TDS (ppm)	SS (ppm)
Check #11:					
8-11-1*	144	.05	11		
-2	144	.07	10		
-3	155	.07	13		
-4	146	.06	8.5		
-5	168	.07	10.5		
-6	154	.08	10		
-7	147	.09	12		
Check #18:					
8-18-1	274	.20	15		
-2	268	.16	13		
-3	256	.16	10		
-4	236	.14	9		
-5	192	.10	8		
-6	204	.12	10		
Check #18:					
N.E. Inlet 8- 3	175	.11	10	124	12.5
N.W. Inlet 8- 4	205	.16	12	138	14
S.E. Inlet 8- 5	181	.10	11.5	127	17.5
Field 8:					
FWA Inflow 8- 1	125	.07	12.2	101	89.4
FWA Outflow 8- 2	182	.08	9.5	124	8.7

*Field No. - Check No. - Probe No., see Fig. VI-6

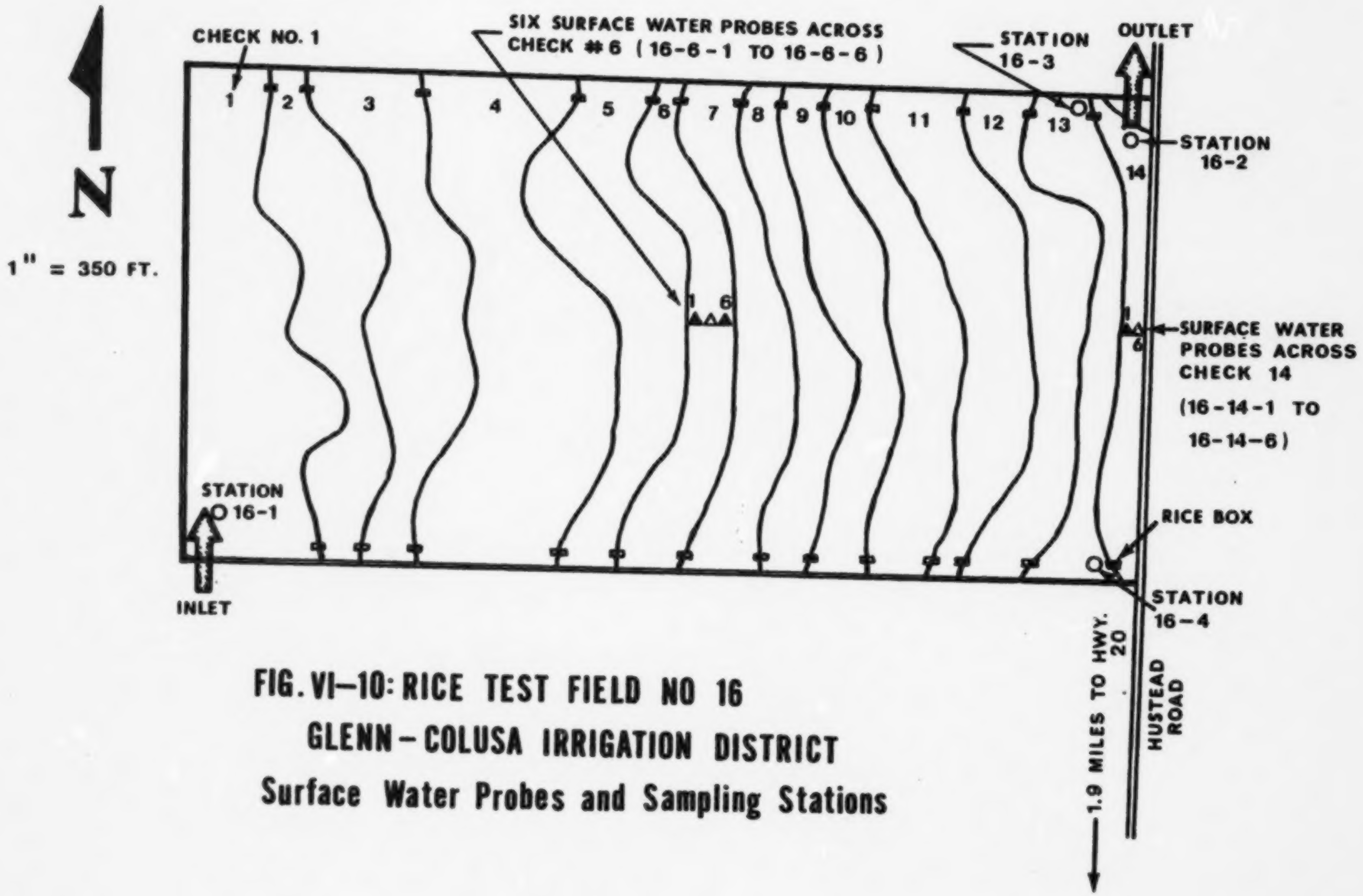

N
1" = 350 FT.
CHECK NO. 1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
SIX SURFACE WATER PROBES ACROSS CHECK # 6 (16-6-1 TO 16-6-6)
STATION 16-3
OUTLET
STATION 16-2
SURFACE WATER PROBES ACROSS CHECK 14 (16-14-1 TO 16-14-6)
RICE BOX
STATION 16-4
STATION 16-1
INLET
1.9 MILES TO HWY. 20
HUSTEAD ROAD

FIG. VI–10: RICE TEST FIELD NO 16
GLENN – COLUSA IRRIGATION DISTRICT
Surface Water Probes and Sampling Stations

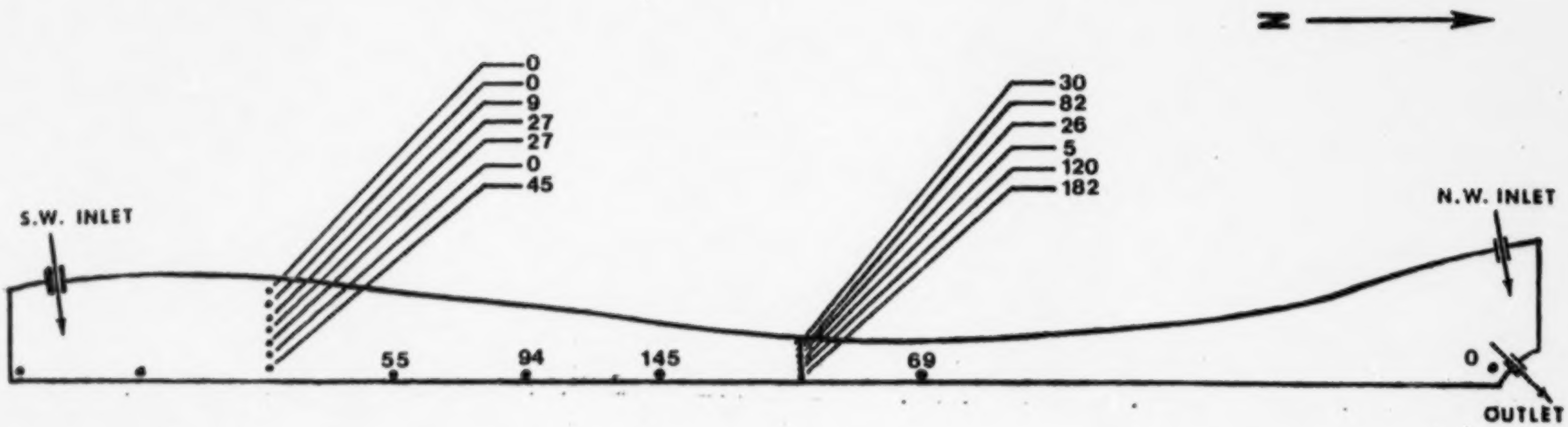

N
S.W. INLET
0
0
9
27
27
0
45
30
82
26
5
120
182
N.W. INLET
55
94
145
69
0
OUTLET

FIG. VI–11:
DYE TRACING STUDIES
RICE TEST FIELD 16, CHECK 14
GLENN-COLUSA IRRIGATION DISTRICT
(DYE CONCENTRATIONS IN PARTS PER BILLION)

S.W. INLET INJECTED
TIME: 12 HOURS
AFTER INJECTION

● - PROBE LOCATION

0
100
200
300
SCALE IN FEET

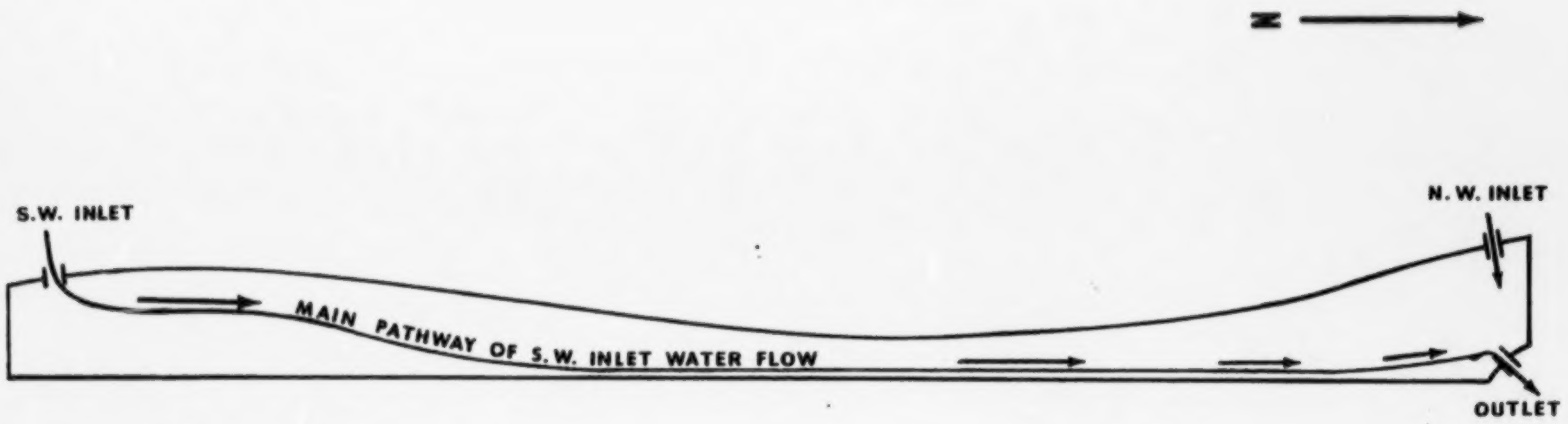
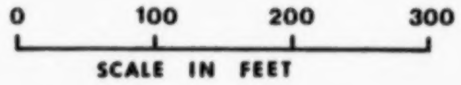

N
S.W. INLET
N. W. INLET
MAIN PATHWAY OF S.W. INLET WATER FLOW
OUTLET

FIG. VI–12:

MAIN PATHWAY OF WATER MOVEMENT
DYE TRACING STUDIES — GCID
RICE TEST FIELD 16, CHECK 14
S.W. INLET INJECTED

(LARGER ARROWS INDICATE
HIGHER DYE CONCENTRATIONS)


0
100
200
300
SCALE IN FEET

Field 8, water quality in checks 6 and 14 as well as the inflow and outflow were closely observed during the whole growing season. Table VI-9 presents a summary on salinity and suspended matter parameters. The within-check, and within-field data give some idea of quality changes as compared to the field inflow and field outflow data.

C. Colusa Basin Drain.

Colusa Basin Drainage Canal (Fig. VI-3), a 70-mile canal, serves as a conveyor of return flows during the irrigation season and of flood runoffs during the nonirrigation season. This flow passes through the outfall gates (see inset for Fig. VI-3) into the Sacramento River above Knights Landing, as well as through the Knights Landing Ridge Cut into the Yolo Bypass. The outfall gates are not opened when the water stage height in the Sacramento River is higher than the drain. This occurs during heavy storm runoffs and large reservoir releases during the winter months; normally from December through March. USGS gaging stations on the Colusa Basin Drain (CBD) are located at Highway 20 (CBD-3) and at the junction of Roads 99E and 108 (CBD-1).

For CBD-3 in the 1975 hydrologic year (October, 1974, to September, 1975), the total flow was 446,880 ac-ft as compared to 295,668 ac-ft for the 1976 hydrologic year. Of these flows, 61% and 72% of the total flows occurred between the months of April and September of 1975 and 1976, respectively. For the 1975 and 1976 hydrologic years the respective mean discharges were 617 and 407 cfs, with a minimum of 59 and 1.3 cfs and maximum of 2470 and 407 cfs, respectively. The flow data for the current hydrologic year 1977 are not available as yet.

For CBD-1 in the 1975 hydrologic year (October, 1974, to September, 1975), the total flow was 274,099 ac-ft as compared to 233,520 ac-ft for 1976

Table VI-9: 1976 Averages - Irrigation Season

Rice Test Fields Surface Water Probès

Field #16

	EC x 10^6 (μmhos/cm)	Cl (mg/ℓ)	Turbidity (JTU)	TDS (ppm)	SS (ppm)
Check #6:					
16- 6-1*	492	.53	22		
-2	501	.43	18		
-3	515	.60	19		
-4	499	.58	15		
-5	489	.55	11		
-6	475	.56	16		
Check #14:					
16-14-1	517	.64	15		
-2	514	.61	12		
-3	511	.62	26		
-4	514	.62	17		
-5	511	.60	13		
-6	507	.63	16		
Check #14:					
N.W. Inlet 16- 3	536	.66	13	326	12
S.W. Inlet 16- 4	513	.61	23	318	9
Field 16:					
FWA Inflow 16- 1	359	.38	22.0	231	12.7
FWA Outflow16- 2	485	.51	11.0	296	10.4

*Field No. - Check No. - Probe No., see Fig. VI-10.

hydrologic year. Of these flows, 74% and 70% of the total flows occurred between the months of April and September of 1975 and 1976, respectively. Similar data for the 1977 hydrologic year are not available as yet.

It is of interest to note the difference between flows at CBD-3 for the two mentioned years. The flow is substantially less in the 1976 hydrologic year because of lower rainfall and heavier downstream reuse of the water. The difference of flow for the CBD-1 for the two years however is not very significant (only 40,579 ac-ft).

Table VI-10 gives the 1976 irrigation seasonal water quality data for the five stations in the Colusa Basin Drain (Fig. VI-3). For comparison purposes, the GCID's supply water is also included in this table. The primary data for these stations are found in Appendix Table 46. As shown in Table VI-10 there is a trend of increasing salinity and suspended matter in the drain from its headwaters to the Knights Landing area. This trend would be expected, since return flows are reused and discharged back into the drain. A recent California Department of Water Resources study in this study area points out that the downstream reuse of return flows results in a basin irrigation season efficiency of about 70% for the 1960-70 period. The quality of these return flows is nearly the same as the quality of the supply waters for the San Joaquin Valley study area.

Tables VI-11 and VI-12 give the two nonirrigation seasons water quality data for 1975-76 and 1976-77, respectively, for five stations in the Colusa Basin Drain (Fig. VI-3). The primary data for these stations are given in Appendix Tables 47 and 48, respectively. Although there was no supply water delivered to the area during these periods, the trend in increasing salinity and suspended matter in the drain from the upper reaches to Knights Landing remained the same as during the irrigation season, but the concentration

Table VI-10: The 1976 (April Through October) Seasonal Water Quality in Several Reaches of the Colusa Basin Drain (CBD)

Station	Description	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
D-14	GCID Supply Water	133	97	8	12
CBD-5 (D-5)	CBD at Sidds Road	322	197	21	48
CBD-4 (D-15)	CBD at Princeton Road	375	230	17	31
CBD-3 (D-12)	CBD at Colusa Bridge, Hwy 20	601	367	44	88
CBD-2	CBD at Davis Weir	634	385	35	57
CBD-1	CBD at Roads 99E and 108	613	373	53	76

Table VI-11: The 1975-1976 (November Through March) Water Quality in Several Reaches of the Colusa Basin Drain (CBD)

Station	Description	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
CBD-5 (D-5)	CBD at Sidds Road	393	241	9	15
CBD-4 (D-15)	CBD at Princeton Road	394	239	31	42
CBD-3 (D-12)	CBD at Colusa Bridge, Hwy 20	720	439	53	74
CBD-2	CBD at Davis Weir	701	430	43	64
CBD-1	CBD at Roads 99E and 108	814	496	44	55

Table VI-12: The 1976-1977 (November Through March) Water Quality in Several Reaches of the Colusa Basin Drain (CBD)

Station	Description	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
CBD-5 (D-5)	CBD at Sidds Road	418	226	78	77	7.9
CBD-4 (D-15)	CBD at Princeton Road	456	271	260	225	8.0
CBD-3 (D-12)	CBD at Colusa Bridge, Hwy 20	893	533	111	130	8.0
CBD-2	CBD at Davis Weir	843	516	119	122	8.0
CBD-1	CBD at Roads 99E and 108	854	514	33	36	8.3

values in general are slightly higher which may be attributed to the absence of supply water (no dilution), lack of precipitation (no runoff), and/or the decreased amounts of flow in the drains.

Figures VI-13 and VI-14 show plots of EC and SS, respectively, for GCID's supply water and two stations on CBD over the period April, 1975, to March, 1977. The values of EC for CBD-1 and CBD-3 are, in general, the same throughout the study period, CBD-3 values being slightly lower than that of CBD-1. This is true because the CBD-3 is in the upper reaches of Colusa Basin Drain while more drainage water contributes to CBD-1 affecting its quality. For CBD-1, the EC was highest in early April, 1975, in January and February of 1976 and 1977, when the flows were lowest. The EC also peaked in June and from late October to early November. In contrast, the peak SS concentration occurred in early September for both irrigation seasons, when the rice fields were drained prior to harvest. The higher values of SS in early March, 1976, and early January, 1977, are attributed to runoff due to precipitation at the time of sampling.

CBD-1 was sampled frequently, and its water quality data are reported in Appendix Tables 49, 50, and 51. Figure VI-15 plots suspended matter throughout the monitored period. Both temporal and spatial differences exist between these stations. Appendix Table 52 contains detailed water quality data for these Colusa Basin Drain stations for June and September of 1976, and January of 1977. They reflect the integration of many lateral drain inputs, such as those given in Appendix Table 39.

Since CBD-1 represents an internal discharge station for the NPDES permittee in the Sacramento Valley, the relations between EC and TDS, and turbidity and SS, were determined. Figure VI-16 shows a plot of the salinity parameters. TDS and EC are highly correlated, with an r-value approaching 1.0.

Figure VI-17 contains a plot of the suspended matter parameters. SS is equally well correlated to turbidity (r = 0.96) as are the salinity parameters.

The major water quality problem in the Colusa Basin Drain appears to be the sediment load, since it is high relative to the Sacramento River, and is noticeable as a plume at the outfall near Knights Landing. The reason(s) why there is such a high suspended sediment load, in spite of the decreased water flow velocity in the lower reaches of Colusa Basin Drain, is yet to be determined.

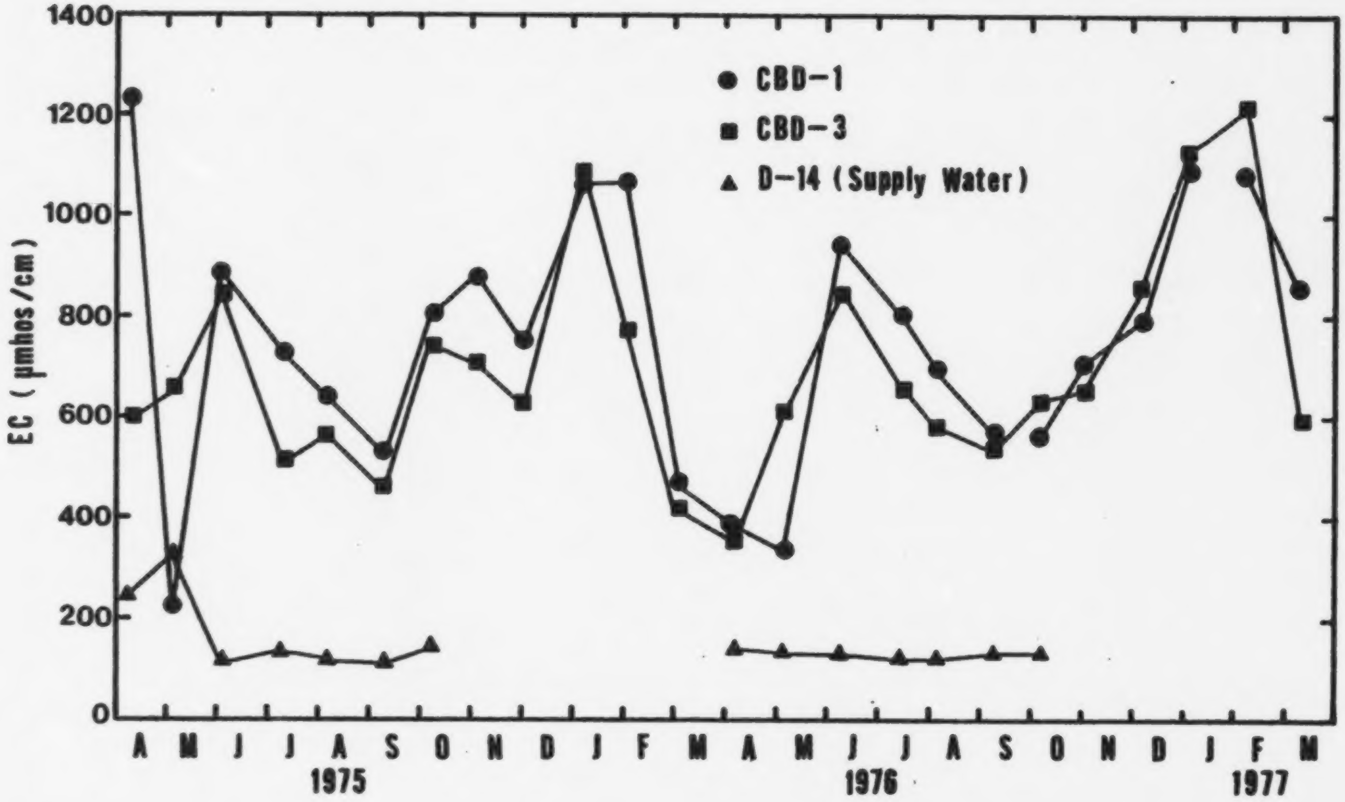


FIG. VI–13: PLOT OF EC FOR STATIONS CBD–1, CBD–3 AND GCID SUPPLY WATER (D–14) FOR APRIL 1975 THROUGH MARCH 1977.

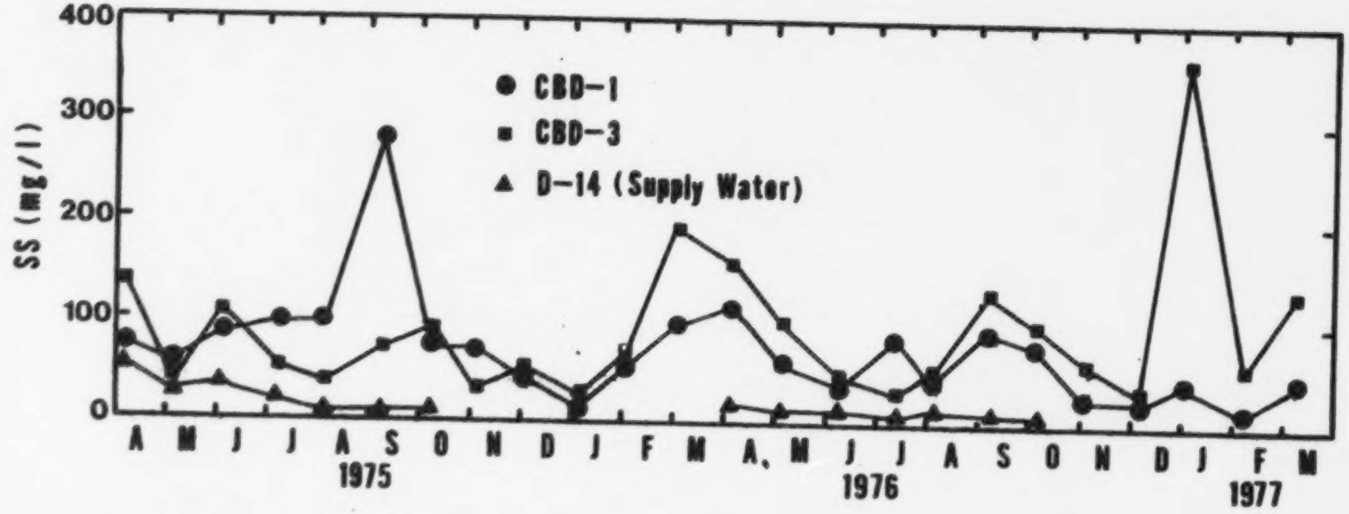


FIG.VI–14: PLOT OF SS FOR STATIONS CBD–1, CBD–3 AND GCID SUPPLY WATER (D–14) FOR APRIL 1975 THROUGH MARCH 1977.

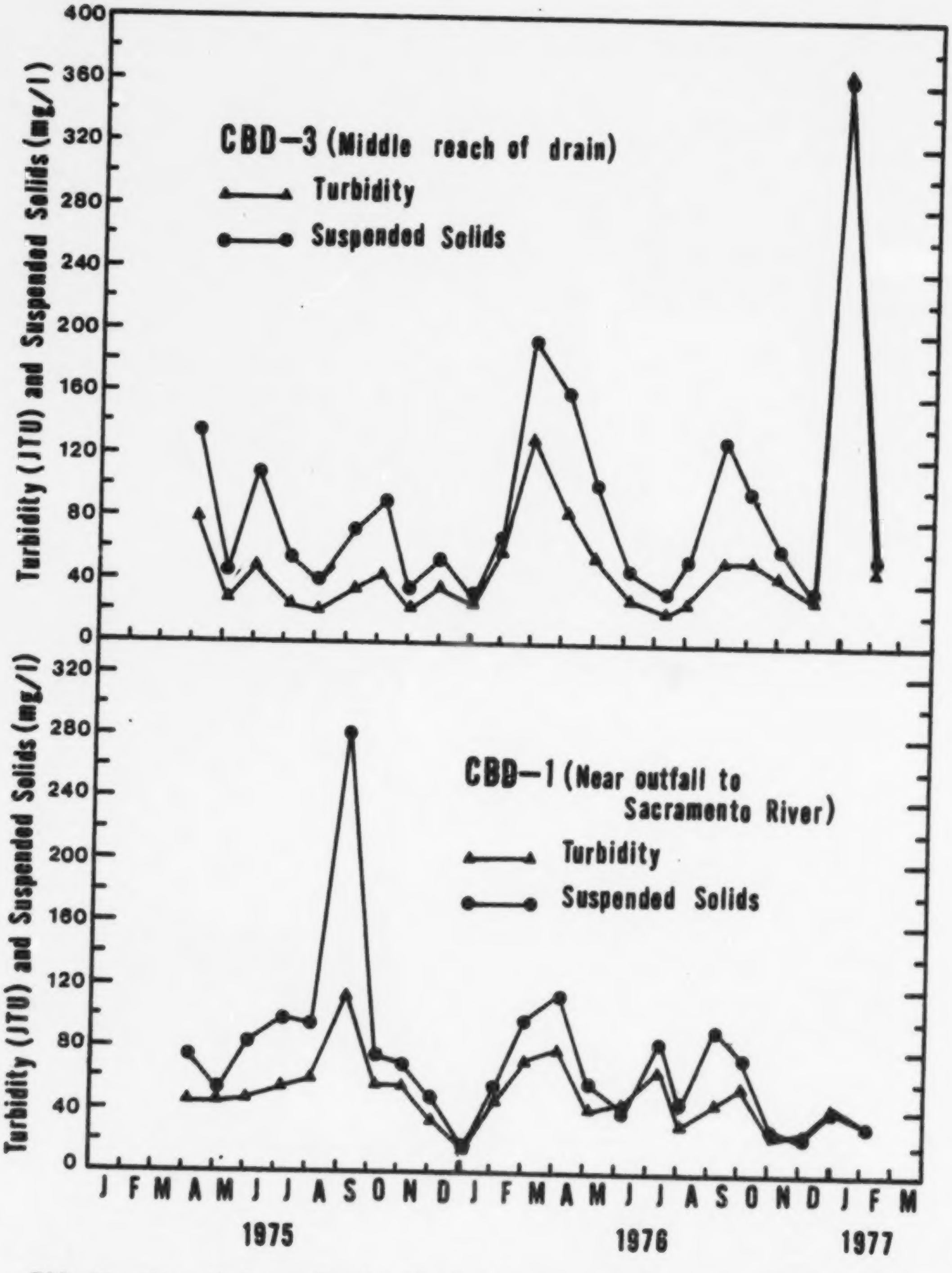


FIG. VI—15: Colusa Basin Drain, monthly data for 1975—77 years.

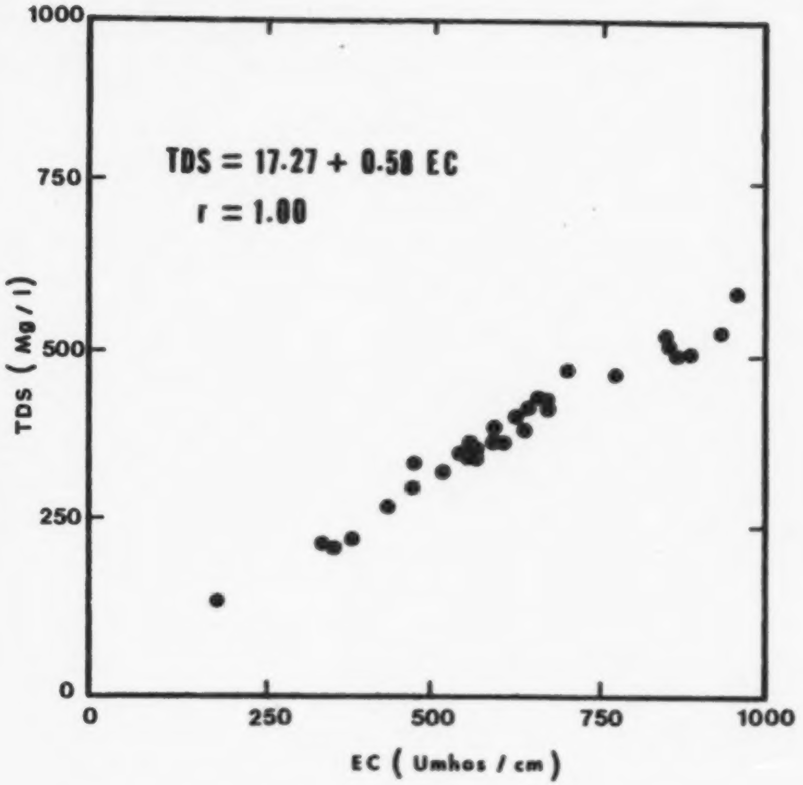


FIG. VI–16 : RELATION BETWEEN TDS AND EC FOR STATION CBD–1 IN 1976.

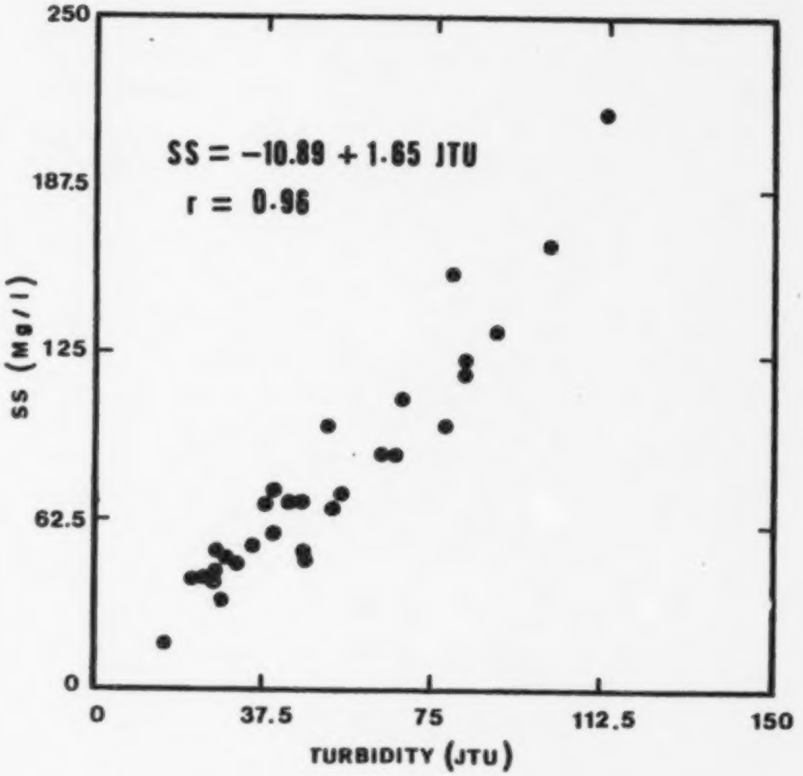


FIG. VI–17 : RELATION BETWEEN SS AND TURBIDITY FOR STATION CBD–1 IN 1976.

CHAPTER VII. TOUR OF FIELD STUDY SITES

A tour of the field study sites was held in July, 1976. Project Cooperators and collaborators assisted in the conduct of the tour. An itinerary is found in Table VII-1. The 1976 irrigation season was at its peak and one could see the irrigation return network and the extensive reuse of the return flows taking place in the grasslands, wildlife habitats and downstream water districts of the Mendota-Crows Landing Return Flow Group. In the Sacramento Valley, the Colusa Basin Drain and GCID were visited including the district supply and drainage network and a rice field.

Forty-two attended the technical meeting prior to the San Joaquin Valley field tour, while 41 participated in the San Joaquin Valley tour, and 35 participated in the Sacramento Valley field locations. A roster of participants is found in Table VII-2, representing diverse interests.

Table VII-1: Irrigation Tailwater Management Field Tour

July 21-22, 1976

July 21	8:00 a.m.	Convene at Central California Irrigation District (CCID) office, 1335 West I Street, Los Banos. Introductions, hand out maps
	8:30	Bus departs from the CCID parking lot Enroute, Los Banos Wildlife Area - Wilbur
	9:00	Henry Wolfsen Property and Salt Slough - Wolfsen
	9:45	Depart from Salt Slough - Cook
	10:20	Fawcett Farms - Fawcett/Bates
	11:20	Depart from Fawcett Farms - Refreshments
	11:40	Russell Avenue Pumps - McCollough
	12:25 p.m.	Broadview Water District Pumps at Fairfax and Nees Avenues - Schnagl/Durrenberger
	1:10	Lunch at Miguel's in Firebaugh
	2:15	Delta-Mendota Canal at the Firebaugh Wasteway - Kenner
	2:50	Depart from the Delta-Mendota Canal. Enroute Broadview Water District - Durrenberger/Schnagl
	3:10	Enrico Farms - Iqbal/Ram
	3:40	Newly constructed drain recapture system - Ram
	3:55	Melon field - Iqbal/Ram/Tanji
	4:30	Return to Los Banos/Depart for Davis
July 22	8:00 a.m.	Depart Voyager Inn for Willows. Enroute, rice production - Milt Miller/Mel Androus/Fran Dubois
	10:00	Convene at Glenn-Colusa Irrigation District Office, 344 E. Laurel, Willows, California. Introductions, handouts
	10:15	Brief introduction to GCID - Haapala
	10:45	Sediment studies on Bondurant Slough/Rice Field No. 4 - Prewitt/Haapala
	11:10	Bondurant Pumping Station/Sampling Site at D-2 - Haapala
	11:20	Chappell Pump and GCID Laterals - Haapala
	11:45	Rice Test Field 13 - Prewitt/Haapala
	12:10-1:10 p.m.	Lunch at Johnson's Steak House in Willows
	1:15-2:00	Rice Test Field 8 - Prewitt/Haapala
	2:10	Sacramento National Wildlife Refuge - Jay Hamernick/Haapala
	2:35	Lenahan Weir/Stone Corral Creek - Haapala
	3:00	Cortina Pumping Plant/Eastside Diversion Channel - Haapala
	3:20	Colusa Basin Drain at CBD-3 (D-12) - Fujii/Tanji
	4:00	Sampling Station CBD-1 On Colusa Basin Drain - Fujii/Tanji
	4:10-4:40	Colusa Basin Drain Outfall near Knights Landing - Fujii/Tanji
	4:40	Return to Davis/Sacramento Airport/etc.

Table VII-2: IRRIGATION TAILWATER MANAGEMENT TOUR

1976

NAME	TITLE	ORGANIZATION AND LOCATION	TELEPHONE	TECH. MEETING 7/20	S.J.V. TOUR 7/21	SAC. V. TOUR 7/22
Mel Andrews	Manager	California Rice Research Board - Yuba City	916-673-6247	✓	✓	✓
Dr. Khairy Aref	Chief, Project Studies Section	SWRCB - Sacramento	916-322-4544			✓
Robert S. Ayers	Soil and Water Specialist	UC-AES - Davis	916-752-1130	✓	✓	✓
C. W. Bates	Manager-Secretary, Return Flow Group Coordinator	CCID - Los Banos	209-826-1421	✓	✓	
Dr. James W. Biggar	Professor of Water Science	LAWR-UCD - Davis	916-752-0681	✓	✓	✓
Mary Blenkush	Lab Helper/Biochemistry Student	LAWR-UCD - Davis	916-752-6947	✓	✓	
Robert Brown	Environmental Specialist	S.J.V. Interagency Drainage Program - Fresno	209-488-5681	✓	✓	
Steve Carlson	Farm Advisor	UC-AES - Orland	916-865-4487	✓	✓	✓
James Chandler	Area Engineering Specialist	USDA-SCS - Fresno	209-487-5125	✓	✓	
Robert Clark	Manager	GCID - Willows	916-934-4695			✓
Sam Cook	Watermaster	CCID - Los Banos	209-826-5176	✓	✓	
Merval Davis	Farmer	Firebaugh		✓		
G. D'Onofrio	Postgraduate Agronomist	LAWR-UCD - (Italy)	916-752-1833			✓
J. W. Dexter	Water Resources Engineer	DWR - Fresno	209-488-5443	✓	✓	
Francis o. DuBois	Farmer	Calif. Rice Research Board - Woodland	916-753-7032			✓
Shelton Dettenberger	Manager	WWD - Firebaugh	209-659-2897		✓	
Alvin Faul	Bus Driver and Farmer	Fresno	209-237-1249		✓	
Roger Fujii	Graduate Student	LAWR-UCD - Davis	916-752-6947	✓	✓	✓
Ted Gerber	Area Engineer	USDA-SCS - Sacramento	916-440-2403			✓
Serge Green	Land and Water Use Analyst	RWQCB - Fresno	209-488-5116	✓		
Richard Haapala	District Engineer	GCID - Willows	916-934-4695			✓
Jay Hamerick	Assistant Manager	USDI-Sac. National Wildlife Refuge - Willows	916-934-4090			✓
Tom Henson	Bus Driver	Woodland	916-662-4047			✓
Mel Holland	Assistant Chief, Planning and Research	SWRCB - Sacramento	916-322-4514			✓
Dr. Arthur G. Hornsby	Project Officer	USEPA - Ada, OK.	405-332-8800	✓	✓	✓
Don Hubble	Civil Engineer	USDA-SCS - Los Banos	209-826-5770	✓	✓	
Mohammed H. Iqbal	Jr. Development Engineer	LAWR-UCD - Davis	916-752-0693	✓	✓	✓
William R. Johnston	Director	S.J.V. Interagency Drainage Program - Fresno	209-488-5681	✓		
D. E. Kienlen	Return Flow Group Chairman	Sac. Valley Water Quality Comm. - Sacramento	916-443-2593			✓
William Kinney	Research Assistant	Ag. Econ.-UCD - Davis	916-752-0213	✓	✓	✓
John Le Compte	Farmer	Dos Palos		✓		
John Lyon	Graduate Student	Ag. Econ.-UCD - Davis	916-752-6081	✓	✓	✓
T. R. McCullough	Assistant Manager	CCID - Los Banos	209-826-1421	✓	✓	

Table VII-2: (continued) IRRIGATION TAILWATER MANAGEMENT TOUR
1976

NAME	TITLE	ORGANIZATION AND LOCATION	TELEPHONE	TECH. MEETING 7/20	S.J.V. TOUR 7/21	SAC. V. TOUR 7/22
Gene Merrill	Land and Water Resource Specialist	RWQCB - Sacramento	916-445-0270	✓	✓	✓
Milton D. Miller	Consultant	California Rice Research Board - Davis	916-753-3837	✓	✓	✓
Robert Miller	Agricultural Engineer	SCS/SWRCB - Sacramento	916-445-7762	✓	✓	✓
George A. Pearson	Soils Specialist	UC-AES - Davis	916-752-2533			✓
Omar Puck	Agricultural Consultant	RWQCB - Sacramento	916-452-3977		✓	✓
Robert Pfitzer	Assistant General Supervisor	CCID - Los Banos	209-826-1421	✓	✓	
David Prewitt	Staff Research Associate	LAWR-UCD - Davis	916-752-0693	✓	✓	✓
William O. Pruitt	Lecturer/Irrigation Engineer	LAWR-UCD - Davis	916-752-1833	✓	✓	✓
Ann Quek	Staff Research Associate	LAWR-UCD - Davis	916-752-6947	✓	✓	✓
Ray Rau	Manager	Panoche Water District - Firebaugh	209-364-6136	✓	✓	
F. E. Redfern	Farmer	Redfern Ranches - Dos Palos		✓		
Roger Robb	Water Management Engineer	USDA-SCS - Davis	916-758-2200	✓	✓	✓
Walt Ryley	Land and Water Use Analyst	RWQCB - Sacramento	916-452-3977	✓	✓	✓
Bonnie Schaffner	Research Writer	S.J.V. Interagency Drainage Program - Fresno	209-488-5681	✓		
Rudy Schnagl	Graduate Student	LAWR-UCD - Davis	916-752-6709	✓	✓	✓
Julie Sellick	Graduate Student	LAWR-UCD - Davis	916-752-6947	✓	✓	✓
William Simmons	Rancher	Oregon			✓	
Brian Smith	Assistant Engineer	DWR - Fresno	209-488-5443	✓	✓	
Craig Stroh	Economist	S.J.V. Interagency Drainage Program - Fresno	209-488-5681	✓	✓	
Leo Stromberg	Farm Advisor	UC-AES - Fresno	209-488-3000	✓	✓	
Kenneth K. Tanji	Lecturer/Associate Water Scientist	LAWR-UCD - Davis	916-752-0683	✓	✓	✓
Ronald H. Van De Pol	Land and Water Use Specialist	RWQCB - Sacramento	916-452-3977	✓	✓	✓
L. D. Whittig	Professor of Soil Science	LAWR-UCD - Davis	916-752-1406			✓
Roger Wilbur	Wildlife Habitat Supervisor	Calif. Dept. of Fish and Game - Los Banos	209-826-0463		✓	
N. B. Wolfson	Director	GCID - Los Banos	209-826-4835	✓	✓	
Lynn Wood	Soil Scientist	USEPA - Ada, OK.	405-332-8800	✓	✓	✓

SWRCB - State Water Resources Control Board
RWQCB - Regional Water Quality Control Board
BWD - Broadview Water District
CCID - Central California Irrigation District 1/
GCID - Glenn-Colusa Irrigation District
DWR - Department of Water Resources
SCS - Soil Conservation Service
ERS - Economic Research Service
EPA - Environmental Protection Agency
LAWR - Department of Land, Air and Water Resources
AES - Cooperative (Agricultural) Extension Service
UCD - University of California, Davis

Appendix Table 1:

Water Flow and Quality Data Supply Station S-1

(Head of Arroyo Canal) Mendota-Crows Landing Return

Flow Group. November 1975 through March 1977.

Date	Monthly diversion (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	3,850	400	254	10	19	0.18	-
12-1	220	-	-	-	-	-	-
1-7-76	4,522	-	-	-	-	-	-
2-5	7,160	531	331	22	32	0.10	-
3-3	9,291	689	395	18	25	0.32	-
4-7	13,418	638	378	38	73	0.40	-
5-5	20,378	481	262	43	122	0.20	-
6-2	27,757	543	307	59	139	0.15	-
7-7	29,032	513	297	38	73	0.35	-
8-4	28,019	511	302	46	93	0.05	7.9
9-8	19,926	568	319	28	51	0.15	8.3
10-6	11,736	714	419	39	55	0.10	7.9
11-3	1,629	915	520	22	38	0.22	8.0
1-5-77	877	-	-	-	-	-	-
2-2	5,956	1,157	669	21	3	0.46	8.4
3-2	12,353	1,138	627	20	38	0.15	8.0

Appendix Table 2:

Water Flow and Quality Data Supply Station S-2 (Delta-Mendota Canal at Firebaugh Wasteway) Mendota-Crows Landing Return Flow Group. November 1975 through March 1976.

Date	Monthly diversion (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	10,870	386	237	11	17	0.15	-
1-7-76	47,683	-	-	-	-	-	-
2-5	59,862	689	421	27	45	0.10	-
3-3	66,128	981	561	18	29	0.53	-
4-7	73,798	405	276	25	39	0.22	-
5-5	123,201	313	187	40	97	0.10	-
6-2	153,684	391	227	48	92	0.10	-
7-7	168,572	477	265	38	67	0.35	-
8-4	151,020	614	365	35	68	0.14	8.0
9-8	97,660	427	252	32	57	0.10	8.2
10-6	71,037	767	443	80	126	0.10	7.7
11-3	1,873	601	337	9	9	0.05	7.7
1-5-77	16,409	-	-	-	-	-	-
2-2	46,918	752	430	28	1	0.15	8.3
3-2	70,682	1,088	606	8	36	0.15	8.0

Appendix Table 3:

Water Flow and Quality Data, Discharge Station D-1

(Salt Slough at Lander Avenue) Mendota-Crows Landing Return Flow Group

November 1975 through March 1977

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	121	5,030	2,125	1,261	14	22	0.72	-
11-11	187		1,830	1,094	17	26	0.80	-
11-19	188		1,896	1,112	10	16	0.90	-
11-26	173		1,863	1,116	9	15	0.75	-
12-2	87	2,600	2,267	1,407	10	12	1.10	-
12-11	113		2,426	1,501	8	12	1.76	-
12-17	87		2,819	1,697	7	7	1.80	-
12-24	83		2,819	1,838	8	12	2.90	-
12-31	81		3,365	2,051	8	7	2.10	-
1-6-76	65	4,364	3,259	3,017	7	5	2.10	-
1-14	87		3,497	2,218	10	5	2.15	-
1-21	153		3,188	2,145	16	37	2.90	-
1-28	264		2,318	1,616	20	38	2.04	-
2-4	308	9,134	2,040	1,313	34	53	1.55	-
2-11	359		2,170	1,385	43	94	1.55	-
2-18	311		2,372	1,501	25	42	1.78	-
2-25	351		2,488	1,630	30	71	2.10	-
3-3	436	9,404	2,189	1,436	24	41	1.38	-
3-10	435		1,962	1,216	40	74	1.30	-
3-17	266		2,143	1,259	44	72	1.00	-
3-24	135		2,394	1,385	27	37	0.90	-
3-31	202		1,759	1,028	23	35	0.68	-
4-7	256	6,591	1,835	1,100	35	72	1.15	-
4-14	411		1,401	804	34	66	0.60	-
4-21	163		2,381	1,395	24	42	1.12	-
4-28	129		1,923	1,116	22	37	0.62	-
5-5	87	4,013	2,193	1,237	24	52	0.60	-
5-12	151		1,586	902	45	125	0.40	-
5-19	107		1,691	989	31	34	0.40	-
5-26	87		1,984	1,150	23	80	0.55	-

Appendix Table 3: (continued)

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
6-2-76	179	7,384	1,298	732	50	143	0.35	-
6-9	234		1,127	655	52	63	0.45	7.30
6-16	335		1,074	615	72	148	0.45	7.20
6-23	266		1,193	679	69	123	0.45	7.30
6-30	208		1,363	766	51	100	0.50	7.40
7-7	234	5,877	1,317	730	53	95	0.40	7.80
7-15	188		1,383	790	27	63	0.30	7.70
7-21	177		1,499	887	27	65	0.26	7.70
7-28	127		1,656	929	28	66	0.26	7.60
8-4	280	11,530	1,242	718	63	151	0.16	8.00
8-11	359		1,217	1,144	43	101	0.33	7.80
8-18	399		1,065	627	59	139	0.30	8.10
8-25	446		1,328	798	50	126	0.62	8.00
9-1	474	8,299*	1,136	671	39	95	0.52	7.90
9-8	260*		1,491	969	40	104	0.56	8.10
9-15	264*		1,172	709	51	103	0.50	7.60
9-22	266*		1,288	750	34	71	0.45	7.50
9-29	294*		1,159	680	44	92	0.55	7.10
10-6	401	8,108	1,297	751	40	77	0.25	7.70
10-13	188		1,667	982	23	35	0.38	8.50
10-20	159		1,701	992	23	48	0.60	8.30
10-27	327		-	-	-	-	-	-
11-3	250	7,458	1,812	1,082	29	58	0.82	8.70
11-10	222		1,982	1,206	24	37	0.95	7.60
11-17	361		2,023	1,263	44	85	1.30	7.70
11-24	186		2,309	1,385	22	23	0.90	7.70
12-1	137	3,289	2,690	1,627	17	16	0.75	7.80
12-8	93		2,618	1,571	18	18	0.85	7.70
12-15	115		2,830	1,663	22	26	0.68	7.80
12-22	93		2,775	1,611	6	35	0.95	7.70
12-29	93		2,701	1,599	9	35	0.95	8.00

*Assumed same as 1975.

Appendix Table 3: (continued)

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
1-5-77	143	7,188	2,801	1,654	13	25	1.96	8.20
1-12	236		3,125	2,025	18	23	2.75	7.80
1-19	244		3,336	2,251	11	23	3.70	8.40
1-26	288		3,333	2,222	29	42	3.35	8.40
2-2	335	5,821	3,049	1,982	29	47	3.00	8.20
2-9	296		3,547	2,360	29	68	3.63	7.70
2-16	226		3,496	2,251	23	59	3.20	7.90
2-23	103		2,967	1,745	20	65	1.05	7.70
3-2	113	5,671	3,547	2,368	15	45	2.48	8.00

Appendix Table 4:

Water Flow and Quality Data, Discharge Station D-2
(Mud Slough North) Mendota-Crows Landing Return Flow Group
November 1975 through March 1977

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	264	9,185	1,214	729	34	70	1.00	-
11-11	342		1,490	894	20	29	1.46	-
11-19	414		1,605	984	18	25	1.65	-
11-26	315		1,738	1,080	22	39	1.70	-
12-2	179	3,481	2,219	1,349	21	42	2.20	-
12-11	114		2,483	1,538	24	41	2.25	-
12-17	87		2,980	1,917	20	32	2.55	-
12-24	98		3,161	2,014	29	45	2.40	-
12-31	56		3,477	2,214	17	22	2.40	-
1-6-76	49	9,559	3,835	2,581	32	63	2.90	-
1-14	128		3,497	2,205	25	48	3.00	-
1-21	772		2,429	1,655	34	27	2.70	-
1-28	506		2,914	2,051	42	65	3.02	-
2-4	351	7,980	3,188	2,201	43	62	3.72	-
2-11	330		3,290	2,216	40	63	3.85	-
2-18	230		4,016	2,881	26	33	5.00	-
2-25	167		3,446	2,326	48	88	4.02	-
3-3	222	3,938	3,923	2,747	22	27	4.80	-
3-10	136		708	424	85	126	0.38	-
3-17	99		3,566	2,300	66	110	3.80	-
3-24	98		3,333	2,119	75	130	3.30	-
3-31	97		3,290	2,135	58	105	3.55	-
4-7	87	2,003	3,188	1,967	75	134	2.75	-
4-14	103		4,386	2,539	32	62	4.02	-
4-21	43		3,125	1,986	70	123	3.05	-
4-28	17		4,000	2,626	30	73	3.65	-
5-5	32	420	2,907	1,795	64	109	2.60	-
5-12	10		3,759	2,422	50	94	3.50	-
5-19	6		4,820	3,266	57	86	4.00	-
5-26	8		4,193	2,791	49	96	4.18	-

Appendix Table 4: (continued)

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
6-2-76	4	82	5,320	3,689	76	142	4.90	-
6-9	2		6,108	4,307	120	160	0.50	7.50
6-16	3		6,036	4,112	175	238	5.36	7.70
6-23	3		626	434	78	107	5.36	7.60
6-30	3		4,447	2,997	165	256	4.12	7.80
7-7	2	76	4,971	3,301	210	303	4.24	7.70
7-15	3		2,774	1,741	150	290	2.16	7.60
7-21	3		2,258	1,367	205	321	1.72	7.60
7-28	2		2,980	1,910	150	280	2.30	7.70
8-4	3	363	2,328	1,311	185	298	1.52	8.80
8-11	5		1,896	1,176	230	167	1.76	8.00
8-18	6		1,672	1,014	50	92	1.30	7.90
8-25	37		1,809	1,175	55	110	1.40	7.60
9-1	25	1,731	1,678	1,034	47	76	1.30	8.20
9-8	25		1,902	1,229	115	190	1.68	8.40
9-15	27		1,372	836	73	113	1.10	7.60
9-22	118		966	566	78	107	0.56	7.80
9-29	140		1,490	875	26	46	0.92	7.80
10-6	290	8,691	1,086	641	38	38	0.62	7.50
10-13	209		1,259	735	24	33	0.90	8.70
10-20	431		1,220	723	26	42	0.90	8.40
10-27	307		1,302	748	26	26	0.82	8.70
11-3	503	8,785	1,168	666	19	24	0.70	8.60
11-10	389		1,419	844	22	21	0.90	7.40
11-17	304		1,643	986	26	34	1.15	7.30
11-24	194		1,905	1,141	32	43	1.40	7.40
12-1	108	1,833	2,353	1,461	44	54	1.60	7.60
12-8	86		3,199	2,047	41	55	2.48	7.60
12-15	48		3,472	2,248	33	46	2.60	7.90
12-22	51		3,435	2,171	28	70	2.60	7.90
12-29	48		3,783	2,476	29	36	2.80	8.00

Appendix Table 4: (continued)

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
1-5-77	373	9,695	3,115	1,833	26	28	2.40	8.30
1-12	284		3,268	2,165	21	27	3.35	8.30
1-19	276		3,311	2,110	22	28	3.28	8.50
1-26	301	6,708	3,086	1,907	23	28	2.70	8.40
2-2	503		3,106	1,919	32	39	2.55	8.50
2-9	333		3,599	2,240	45	158	2.90	7.80
2-16	120		4,148	2,767	67	122	3.42	7.70
2-23	109		4,532	3,052	32	108	3.76	8.20
3-2	55	1,422	4,012	2,561	28	45	2.80	8.30

Appendix Table 5:

Water Flow and Quality Data, Discharge Station D-3
(Orestimba Creek) Mendota-Crows Landing Return Flow Group
November 1975 through March 1977

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	0	212	-	-	-	-	-	-
11-11	1		-	-	-	-	-	-
11-19	4		-	-	-	-	-	-
11-26	7		-	-	-	-	-	-
12-2	4	79	677	418	10	8	0.20	-
12-11	2		-	-	-	-	-	-
12-17	0		-	-	-	-	-	-
12-24	3		-	-	-	-	-	-
12-31	3		-	-	-	-	-	-
1-6-76	1	295	714	443	8	17	0.05	-
1-14	1		-	-	-	-	-	-
1-21	3		962	647	47	78	0.20	-
1-28	6		797	517	30	42	0.00	-
2-4	5	170	864	600	19	9	0.20	-
2-11	12		850	519	15	15	0.20	-
2-18	9		1,085	669	62	100	0.58	-
2-25	5		1,172	703	11	26	0.58	-
3-3	24	859	1,141	701	29	41	0.52	-
3-10	60		3,333	2,220	52	86	3.70	-
3-17	32		1,154	713	87	141	0.70	-
3-24	16		528	331	48	67	0.25	-
3-31	32		490	295	200	270	0.22	-
4-7	62	1,331	615	370	140	192	0.48	-
4-14	38		544	324	60	110	0.22	-
4-21	32		592	344	68	117	0.20	-
4-28	89		559	333	250	154	0.22	-
5-5	65	1,881	554	308	230	276	0.20	-
5-12	101		720	427	220	471	0.43	-
5-19	38		721	430	185	272	0.35	-
5-26	44		753	447	82	149	0.42	-

Appendix Table 5: (continued)

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
6-2-76	20	1,104	700	413	205	285	0.42	-
6-9	17		560	373	420	579	0.40	8.10
6-16	22		795	468	315	401	0.55	7.75
6-23	71		890	498	230	314	0.55	7.90
6-30	17		650	387	360	476	0.40	7.60
7-7	42	1,426	772	441	305	516	0.40	7.70
7-15	38		691	422	260	438	0.14	7.60
7-21	38		748	485	185	369	0.10	8.00
7-28	38		614	369	315	552	0.10	7.90
8-4	34	1,669	726	425	155	259	0.15	8.00
8-11	24		701	416	87	147	0.28	8.10
8-18	38		857	510	215	248	0.50	8.30
8-25	119		919	554	112	234	0.62	7.90
9-1	18	1,679	773	454	345	476	0.28	7.90
9-8	7		797	493	57	74	0.45	8.30
9-15	137		907	529	49	75	0.60	7.80
9-22	32		907	540	9	13	0.62	7.90
9-29	93		815	464	185	420	0.38	7.40
10-6	93	1,092	648	372	36	54	0.15	7.60
10-13	2		752	421	24	21	0.18	8.30
10-20	5		1,370	805	38	75	0.60	8.40
10-27	20		835	481	9	8	0.22	8.60
2-9-77	14	269	1,360	810	8	12	0.55	7.80
2-16	10		1,244	742	9	11	0.40	8.00
2-23	19		1,688	1,096	6	11	0.75	8.40
3-2	40	761	1,506	920	17	22	0.60	8.40

Appendix Table 6:

Water Flow and Quality Data, Internal Station I-1
(CCID Main Canal) Mendota-Crows Landing Return Flow Group
November 1975 through March 1977.

Date	Monthly diversion (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
2-5-76	2,982	718	443	26	43	0.20	-
3-3	3,745	1,154	694	26	36	0.65	-
4-7	9,762	699	412	50	83	0.40	-
5-5	11,894	610	366	87	176	0.45	-
6-2	11,468	760	443	116	193	0.52	-
7-7	11,359	873	449	90	137	0.62	7.9
8-5	10,666	907	539	57	95	0.40	7.8
9-8	7,170	794	495	46	76	0.50	8.2
10-6	466	669	385	34	41	0.10	7.9
3-2-77	103	1,632	995	30	61	0.83	8.1

Appendix Table 7:

Water Flow and Quality Data, Internal Station I-2
(Mud Slough South at Highway 152) Mendota-Crows Landing
Return Flow Group, November 1975 through February 1976

Date	Monthly Discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-575	-	1,821	1,135	17	21	1.75	-
12-3	-	2,483	1,632	15	18	2.90	-
1-7-76	-	3,161	2,220	9	12	3.65	-
2-4	-	3,188	2,392	32	55	4.40	-

Appendix Table 8:

Water Flow and Quality Data Internal Station I-3 (Bennett Drain at Britto Road) Mendota-Crows Landing Return Flow Group. November 1975 through March 1977

Date	Monthly Discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	-	3,148	1,934	32	56	1.20	-
12-3	-	2,745	1,862	27	35	5.15	-
1-7-76	-	2,483	1,734	43	73	4.25	-
2-4	-	3,000	2,221	20	19	1.35	-
3-4	264	2,189	1,328	34	58	0.78	-
4-7	349	2,488	1,511	33	57	0.98	-
5-5	254	5,556	3,693	31	54	2.40	-
6-1	215	2,800	1,757	37	79	1.15	-
7-7	171	2,209	1,307	42	36	1.00	7.6
8-4	437	1,946	1,237	27	51	0.80	7.8
9-8	21[*]	1,946	1,236	38	66	0.85	8.1
10-5	278[†]	1,334	786	26	48	0.36	7.6
11-3	75[†]	2,857	1,946	26	36	4.43	8.5
12-15	4[†]	3,459	2,455	59	72	4.85	8.0
1-4-77	44[†]	3,061	1,863	38	70	1.35	8.1
2-2	111[†]	5,000	3,401	17	22	2.38	8.1
3-2	-	6,993	4,670	11	23	2.10	8.2

[*] Estimated and measured.

[†] Estimated.

Appendix Table 9:

Water Flow and Quality Data, Internal Station I-5
(Camp 13 Slough) Mendota-Crows Landing Return Flow Group
November 1975 through March 1977

Date	Monthly Discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	1,140	3,778	2,681	31	57	5.58	-
12-3	1,026	5,548	4,252	8	18	9.60	-
1-7-76	514	5,215	4,090	6	13	7.44	-
2-4	998	4,636	3,483	87	208	5.84	-
3-4	1,317	6,220	4,589	58	190	7.40	-
4-7	1,204	5,025	3,599	61	128	5.08	-
5-5	1,400	4,546	3,324	120	197	5.36	-
6-1	2,253	3,800	2,719	195	382	4.35	-
7-7	1,244	4,100	2,843	350	233	4.72	7.9
8-4	1,234	3,322	2,280	200	474	3.40	7.8
9-8	2,021	4,755	3,467	115	285	5.30	8.3
10-6	3,388	1,682	1,097	160	267	1.50	7.8
11-3	944	3,068	2,125	94	159	3.23	8.5
12-15	1,131	2,914	2,002	44	69	2.85	8.2
1-5-77	657	5,548	4,036	17	13	7.46	8.3
2-2	494	4,405	3,134	175	297	4.20	8.3
3-2	1,234	5,153	3,774	55	216	5.08	8.0

Appendix Table 10:

Water Flow and Quality Data, Internal Station I-6 (Panoche Drain)
Mendota-Crows Landing Return Flow Group
November 1975 through March 1977

Date	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	1,810	2,488	1,661	81	232	3.62	-
12-3	1,783	2,544	1,888	83	218	4.30	-
1-7-76	2,634	1,798	1,223	150	401	2.75	-
2-4	3,062	2,040	1,411	120	196	3.18	-
3-4	3,525	2,198	1,448	160	256	2.88	-
4-7	2,358	3,400	2,361	145	281	5.22	-
5-5	4,713	2,381	1,597	205	380	3.30	-
6-2	3,142	3,224	2,278	250	189	5.05	-
7-7	2,700	3,106	2,037	74	125	4.60	7.8
8-4	2,940	2,730	1,784	160	328	3.65	7.8
9-8	2,364	3,252	2,359	130	356	5.20	8.1
10-6	1,652	4,419	3,107	250	557	7.55	7.8
11-3	1,819	3,049	2,040	74	172	3.76	8.6
12-15	2,489	2,931	1,970	295	502	3.60	7.9
1-5-77	2,390	3,322	2,239	88	206	4.30	8.2
2-2	1,310	5,556	3,855	155	278	8.20	8.2
3-2	1,680	5,379	3,858	62	241	8.56	8.2

Appendix Table 11:

Water Flow and Quality Data, Internal Station I-7
(Firebaugh Wasteway) Mendota-Crows Landing Return Flow Group
November 1975 through March 1977

Date	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	-	718	450	21	4	0.45	-
2-4-76	-	1,546	655	55	100	0.88	-
3-3	-	1,378	884	17	16	0.65	-
4-7	-	2,107	1,456	68	127	1.80	-
5-5	-	1,471	1,004	56	99	1.20	-
6-2	-	1,330	839	51	80	0.92	-
7-7	-	1,597	976	57	95	1.40	7.5
8-4	-	1,281	806	54	75	0.68	7.9
9-8	-	1,164	717	32	78	0.75	8.1
10-6	-	2,472	1,632	33	51	2.22	8.6
11-3	-	1,066	630	18	26	0.55	8.6
1-5-77	-	3,104	2,083	27	32	2.60	8.4
2-2	-	2,551	1,710	33	45	1.40	8.3
3-2	-	1,748	1,055	21	34	0.50	7.5

Appendix Table 12:

Water Flow and Quality Data, Internal Station I-8

(Turner Island Inflow) Mendota-Crows Landing Return Flow Group

November 1975 through March 1977

Date	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
11-5-75	0	1,114	626	8	8	0.10	-
1-7-76	634	-	-	-	-	-	-
2-4	796	911	558	39	80	0.05	-
3-4	1,397	990	600	34	66	0.20	-
4-7	2,044	857	495	34	71	0.20	-
5-5	2,017	758	446	38	98	0.15	-
6-2	2,595	1,097	458	87	197	0.57	-
7-8	3,555	754	415	34	45	0.30	7.6
8-4	3,556	788	464	84	207	0.05	7.8
9-8	1,415	769	456	59	180	0.22	8.0
10-6	801	975	568	19	29	0.15	7.7
11-3	220	1,131	652	14	23	0.20	8.6
2-3-77	770	1,188	685	24	6	0.10	8.5
3-2	1,748	1,399	796	30	69	0.10	8.0

Appendix Table 13:

Water Flow and Quality Data, Internal Station I-9
(Mud Slough below Geis Ditch) Mendota-Crows Landing Return Flow Group
March 1976 through March 1977

Date	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
3-4-76	5,556	3,542	2,069	71	125	4.88	-
4-7	2,798	3,984	2,796	54	108	5.83	-
5-5	4,410	3,185	2,292	88	184	5.77	-
6-1	3,698	3,224	2,226	92	175	5.35	-
7-7	3,272	3,264	2,187	49	81	4.89	8.1
8-4	5,565	3,322	2,316	98	180	5.05	8.1
9-8	1,738	3,150	2,189	71	144	4.80	8.3
10-5	2,347	2,789	1,844	32	49	3.90	7.5
11-3	3,734	2,825	1,902	34	58	3.82	8.6
12-15	2,462	3,751	2,677	34	43	4.55	8.0
1-5-77	6,271	3,807	2,602	44	52	5.00	8.3
2-1	4,365	4,310	3,062	39	49	6.10	8.3
3-2	-	4,895	3,519	43	102	5.60	7.7

Appendix Table 14:

Detailed Water Quality Analysis for Discharge, Supply and Internal Stations

Mendota-Crows Landing Return Flow Group*

1976-1977

Date	EC (umhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml	
		meq/l						mg/l								Total	Fecal
Discharge Station D-1 (Salt Slough at Lander Avenue)																	
3-3-76	2189	11.75	6.00	4.00	3.45	10.21	8.58	4.930	1.100	0.20	3.350	0.080	0.6	--	--	--	--
6-2	1298	7.20	3.00	3.30	3.13	6.59	3.35	2.116	2.060	0.04	0.012	0.004	9.6	10.60	8.5	0	0
9-8	1491	8.75	3.70	3.70	3.76	8.60	4.15	2.205	1.160	0.24	0.733	0.072	2.4	9.12	8.1	0	0
1-5-77	2801	16.75	6.75	5.25	4.38	12.41	11.30	4.080	1.600	0.25	2.200	0.030	0.6	10.30	8.2	100	0
Discharge Station D-2 (Mud Slough North)																	
3-3-76	3923	25.50	9.00	6.00	4.80	17.03	20.50	8.964	1.850	0.15	6.830	0.134	1.2	--	--	--	--
6-2	5320	39.00	7.75	12.75	5.22	25.63	28.00	2.817	2.770	0.03	0.016	0.001	6.0	11.20	8.8	0	0
9-8	1902	11.25	5.00	2.00	4.39	7.76	7.00	1.863	1.600	0.10	0.135	0.028	0.6	9.00	8.4	0	0
1-5-77	3115	20.25	5.50	5.75	5.64	12.75	13.00	3.800	2.370	0.28	1.120	0.029	0.6	10.30	8.3	0	0
Discharge Station D-3 (Orestimba Creek)																	
3-3-76	1141	4.40	4.00	2.50	4.18	3.61	3.70	4.629	0.750	0.05	3.800	0.029	0.6	--	--	--	--
6-2	700	3.70	1.75	2.05	2.19	2.64	2.15	2.820	1.140	0.06	1.600	0.020	0.6	10.40	8.2	0	100
9-8	797	3.60	2.20	1.60	2.56	3.03	2.50	2.335	0.770	0.03	1.525	0.010	0.6	8.97	8.3	0	200
Supply Station S-1 (Head of Arroyo Canal)																	
3-3-76	689	3.50	1.75	1.45	1.77	2.73	1.85	2.263	0.960	0.04	1.250	0.013	0.6	--	--	--	--
6-2	543	2.90	1.20	1.35	1.72	2.51	1.30	1.366	1.260	0.04	0.064	0.002	0.6	11.20	8.3	0	0
9-8	568	2.60	1.35	1.05	1.93	2.49	1.04	1.305	0.670	0.03	0.595	0.010	3.6	8.86	8.3	0	600
Supply Station S-2 (Delta-Mendota Canal at Firebaugh Wasteway)																	
3-3-76	981	5.10	2.40	2.10	2.40	4.25	2.90	2.636	1.030	0.07	1.500	0.036	1.8	--	--	--	--
6-2	391	2.05	0.88	1.20	1.41	1.80	0.70	0.638	0.570	0.03	0.036	0.002	1.2	12.00	8.1	0	100
9-8	427	1.90	0.90	1.00	1.67	1.84	0.64	1.079	0.450	0.05	0.570	0.009	0.6	9.25	8.2	0	100
Internal Station I-1 (CCID Main Canal)																	
3-3-76	1154	5.30	3.20	2.00	3.36	3.99	4.10	3.459	0.660	0.04	2.750	0.009	0.6	--	--	--	--
6-2	760	4.40	1.70	1.65	1.98	2.81	2.87	2.908	0.940	0.04	1.800	0.108	1.8	10.30	8.1	0	200
9-8	794	3.60	2.00	1.60	2.35	3.00	2.70	1.833	0.660	0.04	1.120	0.130	0.6	8.86	8.2	0	100
Internal Station I-3 (Bennet Drain at Britto Road)																	
3-3-76	2189	10.35	5.50	5.00	3.24	10.49	7.50	6.046	2.150	1.35	2.450	0.096	4.2	--	--	--	--
6-1	2800	15.25	7.00	7.75	4.18	13.45	11.62	3.608	1.660	0.04	1.800	0.108	4.2	10.40	8.1	0	0
9-8	1946	9.25	5.00	5.00	3.65	8.60	7.50	1.720	1.030	0.17	0.300	0.020	1.2	9.25	8.1	0	100
1-4-77	3061	16.75	8.50	6.75	6.89	13.98	10.90	3.100	2.190	0.76	0.140	0.006	4.8	11.40	8.1	0	400

*Flow, TDS, turbidity, SS and B are given in Appendix Tables 1-13 for the corresponding Stations.

Appendix Table 14: (continued)

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml Total	coliform/100 ml Fecal
		meq/ℓ						mg/ℓ									
Internal Station I-5 (Camp 13 Slough)																	
3-4-76	6220	34.50	25.00	10.25	2.92	30.32	38.00	52.626	1.070	0.03	51.500	0.026	0.6	--	--	--	--
6-1	3800	22.00	14.00	6.75	2.92	17.18	22.00	25.860	1.710	0.09	24.000	0.039	3.0	11.20	8.2	0	0
9-8	4755	26.00	18.50	8.00	3.34	22.07	25.00	38.120	0.450	4.45	33.000	0.220	0.6	8.86	8.3	0	300
1-5-77	5548	36.50	19.50	9.00	3.34	20.52	38.19	23.440	1.290	0.06	22.000	0.093	1.2	11.20	8.3	0	100
Internal Station I-6 (Panoche Drain)																	
3-4-76	2198	11.75	6.00	3.50	2.40	8.58	10.75	14.997	1.400	0.10	13.400	0.097	0.6	--	--	--	--
6-2	3224	20.25	9.75	5.25	2.92	13.91	16.88	20.260	1.490	0.41	18.250	0.111	2.4	10.80	8.2	0	0
9-8	3252	18.00	10.00	5.50	3.76	13.90	16.50	16.030	1.440	0.06	14.400	0.126	0.6	9.25	8.1	0	0
1-5-77	3322	19.25	10.00	5.25	3.13	12.07	18.00	15.240	1.170	0.03	14.000	0.038	0.6	11.00	8.2	0	0
Internal Station I-7 (Firebaugh Wasteway)																	
3-3-76	1378	6.55	4.00	2.25	2.19	4.52	6.60	6.830	1.220	0.08	5.400	0.130	7.2	--	--	--	--
6-2	1330	7.90	3.40	2.30	2.40	4.11	7.00	5.380	1.480	0.12	3.700	0.080	3.0	11.40	8.1	0	0
9-8	1164	6.00	2.60	1.80	2.71	3.93	5.00	2.290	1.680	0.12	0.430	0.060	1.2	9.25	8.1	0	2800
1-5-77	3104	18.50	8.25	5.25	2.30	10.27	18.50	11.360	1.270	0.13	9.900	0.062	1.2	10.67	8.4	0	0
Internal Station I-8 (Turner Island Intake)																	
3-4-76	990	4.20	3.00	1.80	2.71	4.52	2.30	4.399	0.970	0.23	3.300	0.099	0.6	--	--	--	--
6-2	1097	3.60	2.40	1.60	2.40	3.60	1.60	3.258	2.180	0.22	0.800	0.058	0.6	11.40	8.1	0	0
9-8	769	3.30	2.20	1.50	2.66	3.42	1.52	2.185	0.890	0.31	0.920	0.065	3.0	9.25	8.0	0	200
Internal Station I-9 (Mud Slough Below Gels Ditch)																	
3-4-76	3542	20.00	10.00	6.50	3.03	15.96	19.50	17.174	1.610	0.09	15.400	0.074	0.6	--	--	--	--
6-1	3224	20.12	8.50	5.25	2.92	13.35	16.33	12.280	1.330	0.07	10.800	0.079	1.2	11.00	8.2	0	0
9-8	3150	16.50	10.00	7.00	4.18	12.43	16.50	2.312	1.270	0.03	0.772	0.240	0.6	8.86	8.3	0	200
1-5-77	3807	23.00	11.00	6.50	3.34	15.45	21.00	11.300	1.660	0.14	9.400	0.098	0.6	10.17	8.3	0	0

Appendix Table 15:

Locations of Water Sampling Stations in Broadview Water District

Mendota-Crows Landing Return Flow Group

1975-76

No.	Sampling ID	Sampling location (Township, range and section)	Sample Description
1	BWD-1	13S13E16	Water sample from drain along Hudson Avenue in corner of Ashlan Avenue. Gravity inflow to Broadview Water District from Westlands Water District.
2	BWD-2	13S14E9	Water sample from the drain along Firebaugh Canal east of Lyon and south of Shaw Avenue. Inflow to Broadview Water District from Westlands Water District.
3	BWD-3	12S13E33	Water sample from the lower end of the drain at pumps in corner of Nees Avenue and Fairfax Avenue.
4	BWD-4	12S13E33	Water sample from the supply canal along Fairfax Avenue below the drain discharge from pumps, i.e., mixture of DMC and drain water.
5	BWD-5	12S13E21	Water sample from Delta Mendota Canal at Fairfax Avenue.

Appendix Table 16:

Water Flow and Quality Data, Broadview Water District

Mendota-Crows Landing Return Flow Group

November 1975 through March 1977

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
BWD-1 Contiguous Surface Inflow							
12-02-75	13	367	235	72	146	0.20	--
2-05-76	104	392	255	100	180	0.05	--
3-03	180	687	218	1,750	2,886	0.30	--
4-07	67	567	338	360	705	0.38	--
5-05	43	—	—	—	—	—	--
6-02	160	578	342	3,360	1,126	0.30	--
7-07	205	729	407	840	225	0.45	8.1
8-04	242	539	334	210	344	0.32	8.2
12-15	13	689	382	415	601	0.06	8.1
BWD-2 Contiguous Surface Inflow							
12-03-75		438	274	150	289	0.20	--
2-05-76	37	1,821	1,288	240	350	0.90	—
3-03	112	3,446	2,418	37	81	2.50	—
4-07	121	1,378	788	140	193	0.70	—
5-05	122	1,165	758	67	114	0.50	—
6-02	223	1,196	713	47	69	0.45	—
7-07	183	1,124	645	28	29	0.65	7.5
8-04	189	1,134	716	63	89	0.55	8.3
9-08	111	557	349	32	55	0.22	8.6
10-06	41	2,229	1,522	170	246	0.90	7.7
11-03	38	3,659	661	205	352	2.58	8.4
12-15	18	1,013	586	18	15	0.25	7.8
1-05-77	18	1,743	1,035	23	25	0.65	8.0
2-02	6	8,264	5,839	18	23	3.80	8.2
3-02	-	7,531	5,583	39	164	4.40	8.1

Appendix Table 16: (continued)

Date	*Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	pH
BWD-3 Captured Drain Water							
11-05-75	311	2,429	1,678	180	490	1.90	—
1-07-76	976	—	—	—	—	—	—
2-05	2,026	1,889	1,303	200	289	1.15	—
3-03	1,636	4,811	3,447	86	181	4.00	—
4-07	1,279	3,517	2,430	140	250	2.40	—
5-05	1,825	4,184	3,132	185	367	3.50	—
6-02	2,219	2,474	1,646	156	222	1.60	—
7-07	1,979	2,190	1,376	265	363	1.52	7.2
8-04	1,065	1,576	1,031	164	308	0.90	8.0
9-08	36	3,897	3,043	85	245	3.82	8.4
10-06	40	6,064	4,921	7	16	5.00	7.6
11-03	190	5,233	3,750	185	306	3.76	8.5
12-15	-	8,091	6,392	7	10	7.80	8.1
1-05-77	512	3,043	1,951	108	150	1.70	7.9
2-02	1,550	3,226	2,249	83	100	1.60	8.3
3-02	397	6,441	4,691	18	71	3.95	7.7

* BWD 4 - BWD 5

Appendix Table 16: (continued)

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
BWD-4 Deliverd Mixed Water							
11-05-75	783	1,325	841	30	54	0.90	—
1-07-76	2,560	—	—	—	—	—	—
2-05	4,827	1,275	818	73	150	0.68	—
3-03	3,038	3,228	2,269	34	58	2.68	—
4-07	2,067	3,643	2,494	240	567	2.55	—
5-05	3,623	4,098	3,053	170	316	3.50	—
6-02	4,895	1,612	1,025	74	134	0.85	—
7-07	4,585	1,314	785	140	263	0.84	7.8
8-04	1,790	1,064	624	94	173	0.52	8.0
9-08	60	3,786	2,809	6	15	3.20	8.4
10-06	347	—	—	—	—	—	—
11-03	340	—	—	—	—	—	—
1-05-77	1,641	—	—	—	—	—	—
2-02	5,730	2,404	1,545	33	46	1.20	8.3
3-02	722	3,885	2,713	15	23	2.10	7.8
BWD-5 Diverted Canal Water							
11-05-75	472	400	242	10	13	0.10	—
1-07-76	1,384	—	—	—	—	—	—
2-05	2,801	384	268	25	46	0.05	—
3-03	1,402	500	292	25	34	0.20	—
4-07[†]	788	(1,457)/390	(919)/252	(39)/25	(74)/41	(0.82)/0.16	—
5-05[†]	1,798	(3,802)/313	(2,846)/193	(165)/39	(311)/86	(3.05)/0.10	—
6-02	2,676	475	278	34	56	0.30	—
7-07	2,606	502	290	34	58	0.35	7.8
8-04	725	481	293	43	78	0.05	8.0
9-08	24	424	246	25	48	0.05	8.3
10-06	307	791	452	14	23	0.22	7.5
11-03[†]	150	(1,226)/648	(704)/343	(12)/11	(15)/11	(0.55)/0.12	(8.6)/8.1
1-05-77	1,129	—	—	—	—	—	—
2-02[†]	4,180	(1,701)/748	(1,007)/422	(14)/24	(16)/14	(0.90)/0.10	(8.4)/8.2
3-02	325	1,530	900	7	15	0.55	7.8

[†] The values in parentheses are the actual values measured in the laboratory. These values are much higher than the other two samples taken from the DMC canal on the same day, one upstream (PWD-1) and one downstream (S-2) from this sampling site, although they should be almost the same. Therefore, another set of values is presented here which are the average values of the two latter samples, which are more realistic. These latter values are used for flow-weighting and for mass transfer of salts and sediments in Tables V-5 and V-6.

Appendix Table 17:

Detailed Water Quality Analysis for Broadview Water District

Mendota-Crows Landing Return Flow Group*

1976-1977

Date	EC (μmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml Total	coliform/100 ml Fecal
		meq/l						mg/l									
BWD-1 Contiguous Surface Inflow																	
3-3-76	687	3.45	2.75	0.75	1.04	1.99	3.30	4.226	2.36	0.14	1.70	0.026	3.0	--	—	—	--
6-2	578	3.20	1.35	0.75	1.88	1.88	1.95	9.294	7.03	0.27	1.90	0.094	0.6	10.40	8.2	0	0
BWD-2 Contiguous Surface Inflow																	
3-3-76	3446	18.95	12.00	8.00	3.03	15.26	20.50	15.265	1.26	0.24	13.60	0.165	9.6	—	—	—	—
6-2	1196	5.60	3.40	2.30	2.40	5.04	4.15	22.430	12.70	0.80	8.80	0.130	0.6	10.60	8.2	0	0
9-8	557	2.45	1.80	0.90	2.77	2.38	0.64	0.797	0.67	0.03	0.09	0.007	2.4	8.97	8.6	0	0
1-5-77	1743	8.75	5.25	2.63	2.71	6.77	6.55	18.880	1.65	0.90	16.00	0.325	0.6	10.00	8.0	0	0
BWD-3 Captured Drain Water																	
3-3-76	4811	31.00	14.50	9.00	2.82	21.32	30.00	22.832	1.20	0.10	21.40	0.132	0.6	—	—	—	—
6-2	2474	13.50	6.25	5.75	2.51	9.26	13.63	13.550	1.34	0.26	11.80	0.151	0.6	10.60	8.0	0	0
9-8	3897	24.00	12.60	8.00	3.34	15.22	25.00	14.270	2.03	0.07	12.00	0.168	3.0	9.25	8.4	0	200
1-5-77	3043	17.50	9.00	4.50	2.92	11.96	15.00	19.680	1.90	0.95	16.50	0.325	2.4	10.00	7.9	0	0
BWD-4 Delivered Mixed Water																	
3-3-76	3228	20.00	10.00	5.50	2.40	13.99	18.50	15.362	1.04	0.06	14.20	0.062	1.8	—	—	—	—
6-2	1612	8.50	4.20	3.30	1.98	6.11	7.57	7.385	0.89	0.11	6.30	0.085	0.6	11.20	8.0	0	0
9-8	3786	20.50	10.00	6.25	3.34	14.18	18.50	12.270	1.07	0.03	11.00	0.170	0.6	9.25	8.4	0	0
BWD-5 Diverted Canal Water																	
3-3-76	500	2.30	1.35	1.05	1.57	1.99	1.25	2.063	0.84	0.06	1.15	0.013	0.6	—	—	—	—
6-2	475	2.50	1.10	1.25	1.51	2.08	1.13	1.690	0.98	0.02	0.68	0.005	0.6	10.60	8.0	0	0
9-8	424	1.90	0.90	0.90	1.57	1.98	0.60	1.057	0.58	0.02	0.45	0.007	1.2	8.84	8.3	0	1000

*Flow, TDS, turbidity, SS, and B are given in Appendix Table 16 for corresponding Stations.

Appendix Table 18:

Location of Soil Sampling Sites in

Broadview Water District, 1976.

No.	Sampling Date	Sample I.D.	Sampling Location (township, range and section	Sampling Depth, ft.	Crop
1	10-16	BWD-S37	13S13E8	16	Cotton
2	10-16	BWD-S38	12S13E34	9	Wheat
3	10-17	BWD-S39	13S14E18	11	Wheat
4	10-17	BWD-S40	13S14E7	7	Cotton
5	10-17	BWD-S41	13S13E14	14	Wheat
6	10-17	BWD-S42	13S13E2	9	Alfalfa
7	10-17	BWD-S43	13S13E12	8	Wheat

Appendix Table 19:

Soil Analyses in Broadview Water District - 1976

Location	Depth (ft)	Saturation Percentage	EC_e (mmhos/cm)	Cl (meq/l)	SO_4 (meq/l)	B (mg/l)	Soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
BWD 837	0-½	77	3.87	12.0	31.5	2.05	3.82	0.64
	½-1	77	2.48	7.6	13.0	1.85	2.45	0.86
	1-2	81	2.16	6.2	11.0	1.85	2.25	1.03
	2-3	77	5.57	4.1	68.0	2.05	5.50	6.03
	3-4	67	6.23	4.2	77.0	2.40	5.35	63.35
	4-5	50	6.55	5.9	77.5	2.40	4.19	30.32
	5-6	50	6.82	4.7	82.0	3.00	4.36	39.39
	6-7	73	6.39	4.7	78.0	3.60	5.96	38.38
	7-8	49	6.23	5.6	76.0	4.10	3.88	30.63
	8-9	46	5.95	5.1	76.0	4.10	3.48	45.63
	9-10	50	6.25	5.2	76.0	4.10	4.00	51.94
	10-11	53	6.06	4.9	74.0	4.10	4.10	50.03
	11-12	60	6.10	8.0	70.0	4.20	4.68	35.78
	12-13	66	7.81	27.9	70.0	4.45	6.57	29.93
	13-14	44	11.50	73.8	54.0	4.40	6.32	15.67
	14-15	39	12.97	79.4	54.0	3.95	6.41	8.46
	15-16	33	13.68	70.8	54.0	4.15	5.76	7.26
BWD 838	0-½	35	4.44	9.0	42.0	2.45	1.99	0.63
	½-1	36	5.95	24.0	32.0	1.45	2.76	0.76
	1-2	41	3.60	15.8	20.5	1.82	1.90	0.78
	2-3	36	4.41	10.4	46.0	1.53	2.04	13.90
	3-4	30	3.45	4.2	44.0	1.67	1.32	19.23
	4-5	30	3.40	4.9	44.0	1.03	1.31	3.64
	5-6	30	2.14	5.1	17.5	1.00	0.82	0.39
	6-7	38	2.85	8.2	25.0	1.10	1.37	0.50
	7-8	44	3.26	8.0	28.0	1.28	1.83	0.34
	8-9	35	3.17	10.0	22.0	1.40	1.42	0.40
BWD 839	0-½	73	8.98	41.6	36.0	1.97	8.38	3.88
	½-1	77	8.84	42.7	37.0	1.85	8.72	2.76
	1-2	63	9.17	41.0	68.0	2.15	7.38	19.30
	2-3	71	10.23	43.6	76.0	2.70	9.35	20.77
	3-4	79	10.86	42.2	86.0	2.70	10.93	33.09
	4-5	77	11.32	43.9	95.0	3.42	11.17	63.09
	5-6	69	11.04	38.8	100.0	4.70	9.69	33.36
	6-7	63	10.86	36.5	98.0	4.25	8.74	32.40
	7-8	61	9.85	28.6	95.0	3.85	7.74	21.79
	8-9	56	7.43	22.1	74.0	3.00	5.30	3.58
	9-10	50	7.63	30.9	66.0	3.50	4.88	0.34
	10-11	53	9.14	36.3	76.0	4.20	6.19	2.03
BWD 840	0-½	38	5.30	13.9	54.0	2.35	2.34	11.16
	½-1	44	11.96	69.5	62.0	3.25	6.71	14.25
	1-2	51	13.25	70.4	88.0	4.55	8.68	7.30
	2-3	49	12.71	54.3	100.0	3.42	7.94	6.66
	3-4	65	12.62	42.5	110.0	3.50	7.27	6.54
	4-5	54	8.76	19.6	88.0	1.60	6.03	10.78
	5-6	81	6.97	14.8	74.0	1.43	7.26	2.53
	6-7	89	6.97	14.5	68.0	3.00	7.90	9.43

Appendix Table 19: Continued

Location	Depth (ft)	Saturation Percentage	EC_e (mmhos/cm)	Cl (meq/l)	SO_4 (meq/l)	B (mg/l)	Soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
BWD 541	0-½	71	3.10	12.8	17.5	1.30	2.83	0.72
	½-1	70	3.68	15.9	21.0	1.72	3.30	0.48
	1-2	76	6.08	21.0	43.0	2.50	5.93	0.38
	2-3	68	11.78	45.0	100.0	4.32	10.18	22.15
	3-4	68.	11.52	60.8	76.0	3.10	9.95	12.68
	4-5	66	12.32	77.7	62.0	3.00	10.44	18.75
	5-6	66	11.47	77.2	62.0	3.35	9.72	17.89
	6-7	69	9.07	50.9	56.0	3.15	7.99	15.73
	7-8	66	9.66	53.4	60.0	3.35	8.19	18.11
	8-9	66	8.99	48.7	59.0	3.35	7.62	18.21
	9-10	66	8.28	39.6	58.0	3.00	7.02	17.48
	10-11	56	7.57	26.9	68.0	2.70	5.45	14.93
	11-12	64	8.28	37.4	62.0	3.00	6.76	18.13
	12-13	63	8.79	39.9	68.0	3.48	7.03	19.35
	13-14	61	8.76	37.9	70.0	3.17	6.86	17.58
BWD 542	0-½	68	1.69	3.5	10.8	1.30	1.46	0.73
	½-1	71	2.80	9.6	17.5	1.50	2.55	0.39
	1-2	74	6.86	6.5	80.2	4.08	6.48	1.52
	2-3	78	8.08	4.9	96.5	5.74	8.02	128.18
	3-4	104	9.69	5.5	112.5	7.20	12.87	8.29
	4-5	113	10.55	8.3	125.0	7.80	15.19	7.63
	5-6	98	11.99	12.8	136.2	8.35	14.96	44.23
	6-7	85	12.46	19.6	140.0	10.25	13.56	67.25
	7-8	91	13.04	26.4	140.0	14.75	15.22	112.20
	8-9	98	13.37	29.7	136.2	16.25	16.69	97.55
BWD 543	0-½	89	5.04	17.8	37.0	3.12	5.73	0.37
	½-1	91	4.27	17.3	26.0	3.00	4.98	1.08
	1-2	89	5.79	13.4	56.0	3.48	6.58	1.77
	2-3	80	7.56	15.6	76.0	2.82	7.74	13.34
	3-4	84	9.27	15.9	97.5	4.32	9.94	61.63
	4-5	88	9.11	16.8	97.5	5.15	10.20	50.69
	5-6	93	9.40	15.6	97.5	6.50	11.13	60.17
	6-7	91	9.32	14.2	97.5	7.20	10.88	38.03
	7-8	90	10.85	16.2	125.0	10.25	12.50	91.59

Appendix Table 20:

Detailed Soil Analysis in Broadview Water District*

1976

Location	Depth (ft)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	NO_3-N	SAR	pH	Lime (tons/ ac-ft)
		meq/ℓ				meq/ℓ						
BWD S37	0-½	25.50	15.00	7.50	1.00	3.65	11.99	31.50	1.50	7.60	8.0	--
	½-1	19.50	4.25	2.25	0.34	3.39	7.62	13.00	1.43	10.82	8.1	--
	1-2	17.25	3.00	1.25	0.26	2.35	6.21	11.00	1.43	11.83	8.3	--
	2-3	42.00	23.00	9.00	0.28	1.83	4.09	68.00	1.11	10.50	8.4	--
	3-4	49.00	23.00	10.00	0.27	1.57	4.23	77.00	0.79	12.06	8.1	--
	4-5	51.00	25.00	9.00	0.40	1.83	5.92	77.50	1.04	12.25	8.3	--
	5-6	53.00	24.00	11.00	0.30	1.57	4.66	82.00	0.86	12.67	7.9	--
	6-7	50.00	23.00	11.00	0.32	2.09	4.66	78.00	0.96	12.13	8.1	--
	7-8	49.00	24.00	10.00	0.33	1.57	5.64	76.00	1.57	11.88	8.2	--
	8-9	49.00	26.00	9.00	0.30	1.83	5.08	76.00	1.43	11.25	8.0	--
	9-10	48.00	27.00	9.00	0.28	1.57	5.22	76.00	1.64	11.16	8.2	--
	10-11	45.00	23.00	11.00	0.32	1.83	4.94	74.00	1.21	10.91	8.1	--
	11-12	45.00	23.00	11.00	0.37	1.57	8.04	70.00	1.57	10.91	7.9	--
	12-13	58.00	26.00	16.00	0.41	1.57	27.93	70.00	2.14	12.66	8.2	--
	13-14	75.00	42.00	21.00	0.51	1.57	73.76	54.00	8.57	13.44	8.0	--
	14-15	82.00	47.50	22.00	0.66	1.83	79.40	54.00	17.86	13.79	8.1	--
	15-16	82.50	49.00	25.00	0.58	1.83	70.80	54.00	30.00	13.86	8.2	--

*EC_e, B, soluble salts and gypsum are given in Appendix Table 19 for corresponding sites.

Appendix Table 20: (Continued)

Location	Depth (ft)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	NO_3-N	SAR	pH	Lime (tons/ ac-ft)
			meq/ℓ					meq/ℓ				
BWD S38	0-½	25.25	22.75	11.00	0.82	5.74	9.03	42.00	3.21	6.08	8.0	33.2
	½-1	26.20	28.00	15.00	0.59	3.39	23.98	32.00	12.14	5.65	8.3	35.2
	1-2	19.00	12.00	7.50	0.15	2.87	15.80	20.50	1.21	6.08	8.2	58.8
	2-3	20.00	27.00	10.00	0.20	1.83	10.44	46.00	0.06	4.65	8.4	46.0
	3-4	12.20	32.50	5.50	0.16	1.83	4.23	44.00	0.00	2.87	8.3	40.0
	4-5	12.65	32.00	5.50	0.18	1.83	4.94	44.00	0.39	2.91	8.1	32.0
	5-6	9.00	10.50	2.75	0.15	2.09	5.08	17.50	0.46	3.50	8.2	32.0
	6-7	15.25	15.75	4.00	0.23	1.83	8.18	25.00	0.57	4.68	8.2	38.0
	7-8	20.62	12.88	4.38	0.30	2.09	8.04	28.00	0.64	6.91	8.3	48.0
	8-9	21.00	9.50	3.75	0.31	2.61	10.01	22.00	1.71	8.06	8.5	38.0
BWD S39	0-½	52.00	36.00	21.00	2.00	2.61	41.59	56.00	11.43	9.74	8.1	--
	½-1	53.00	35.00	21.50	1.00	2.61	42.73	57.00	8.57	10.20	8.0	--
	1-2	64.00	31.50	18.00	0.83	2.61	41.04	68.00	3.57	12.86	8.0	--
	2-3	79.00	28.00	15.00	0.50	2.08	43.58	76.00	1.43	17.04	8.1	--
	3-4	89.50	28.00	13.00	0.41	2.61	42.17	86.00	0.64	19.23	8.2	--
	4-5	96.50	26.50	19.00	0.42	2.08	43.86	95.00	0.71	20.54	8.3	--
	5-6	95.00	26.00	20.50	0.48	2.61	38.78	100.00	0.71	20.57	8.3	--
	6-7	92.00	26.00	18.00	0.46	2.61	36.53	98.00	0.21	19.90	8.3	--
	7-8	81.50	25.50	17.50	0.51	2.08	28.63	95.00	0.26	17.22	8.2	--
	8-9	55.00	25.00	18.00	0.50	2.09	22.14	74.00	0.50	11.26	8.1	--
	9-10	58.00	25.00	16.00	0.54	2.61	30.89	66.00	0.57	11.86	8.2	--
	10-11	67.00	28.00	19.00	0.55	2.61	36.25	76.00	0.49	13.97	8.4	--

Appendix Table 20: (Continued)

Location	Depth (ft)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	NO_3-N	SAR	pH	Lime (tons/ ac-ft)
		meq/ℓ				meq/ℓ						
BWD S40	0-½	31.00	29.00	10.00	0.85	3.65	13.68	54.00	0.51	6.19	8.1	--
	½-1	83.00	34.00	18.00	1.30	3.13	69.53	62.00	3.04	16.26	8.0	--
	1-2	120.00	28.00	18.00	0.75	3.13	70.37	88.00	3.56	24.04	8.3	--
	2-3	112.00	25.00	21.00	0.50	3.13	54.30	100.00	2.86	25.40	8.2	--
	3-4	116.00	23.00	18.00	0.40	2.09	42.45	110.00	1.96	22.53	8.3	--
	4-5	73.00	22.00	15.00	0.68	2.61	19.60	88.00	0.82	14.31	8.3	--
	5-6	51.00	24.00	15.00	0.74	2.09	14.81	74.00	0.57	10.09	8.2	--
	6-7	45.00	26.00	13.00	0.50	2.09	14.53	68.00	0.33	10.19	8.2	--
BWD S41	0-½	18.50	10.00	4.50	0.95	3.39	12.83	17.50	1.43	7.42	8.2	--
	½-1	22.00	10.50	5.00	0.76	2.87	15.90	21.00	0.54	7.90	8.3	--
	1-2	49.00	12.50	5.00	0.43	2.35	21.01	43.00	0.04	16.57	8.4	--
	2-3	104.00	32.00	13.00	0.35	2.61	44.99	100.00	0.53	21.93	8.3	--
	3-4	95.00	29.00	13.00	0.45	1.57	60.79	76.00	0.71	19.64	8.3	--
	4-5	90.00	33.00	18.00	0.50	2.09	77.71	62.00	0.64	16.87	8.2	--
	5-6	83.00	38.00	18.00	0.80	1.57	77.15	62.00	0.39	15.69	8.0	--
	6-7	61.00	33.00	15.00	0.88	2.09	50.91	56.00	1.21	12.45	7.8	--
	7-8	67.00	33.00	16.00	0.64	2.09	55.43	60.00	0.86	13.06	7.9	--
	8-9	63.00	30.00	15.00	0.65	2.09	48.66	59.00	1.04	12.72	7.9	--
	9-10	53.00	30.00	16.50	0.82	2.09	39.63	58.00	1.43	11.43	7.9	--
	10-11	55.00	32.50	11.00	0.56	1.57	26.94	68.00	1.57	12.79	7.9	--
	11-12	58.00	29.00	15.00	0.60	1.57	37.37	62.00	1.50	12.37	8.0	--
	12-13	65.00	29.00	15.00	0.62	2.09	39.90	68.00	1.71	13.43	8.1	--
	13-14	64.00	30.00	16.00	0.76	3.13	37.92	70.00	1.86	13.80	8.0	--

Appendix Table 20: (Continued)

Location	Depth (ft)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	NO_3-N	SAR	pH	Lime (tons/ ac-ft)
		meq/ℓ				meq/ℓ						
BWD S42	0-½	10.50	4.25	2.25	0.30	3.65	3.51	10.75	0.61	5.82	8.1	32.0
	½-1	16.25	9.25	3.75	0.47	3.13	9.58	17.50	1.86	6.37	8.2	32.0
	1-2	54.00	26.00	9.00	0.52	2.35	6.47	80.20	0.82	12.91	8.2	42.0
	2-3	73.00	23.00	7.00	0.44	2.61	4.92	96.50	0.49	18.85	8.2	40.0
	3-4	94.00	21.00	7.00	0.44	2.09	5.49	112.50	0.44	25.12	8.4	44.0
	4-5	106.00	21.00	7.00	0.45	2.09	8.31	125.00	0.49	26.19	8.4	46.8
	5-6	120.00	20.00	9.00	0.50	2.09	12.82	136.25	0.50	31.51	8.5	41.2
	6-7	128.00	22.00	10.00	0.65	2.09	19.62	140.00	0.50	31.00	8.4	33.2
	7-8	134.00	22.00	11.00	0.50	2.09	26.36	140.00	0.50	32.51	8.4	20.0
	8-9	136.00	22.00	10.00	0.45	2.09	29.74	136.25	0.71	34.00	8.5	25.2
BWD S43	0-½	34.50	15.00	7.50	0.92	3.92	17.76	37.00	0.22	10.29	8.2	--
	½-1	31.00	11.00	4.50	0.80	3.65	17.33	26.00	0.06	11.14	8.2	--
	1-2	41.50	20.00	9.00	0.79	2.61	13.39	56.00	0.03	10.92	8.1	--
	2-3	60.00	24.00	10.00	0.51	3.13	15.64	76.00	0.06	14.55	8.2	--
	3-4	81.00	24.00	11.00	0.40	2.61	15.92	97.50	0.10	18.92	8.2	--
	4-5	83.00	23.00	10.00	0.41	2.61	16.77	97.50	0.24	20.43	8.3	--
	5-6	84.00	21.00	10.00	0.43	2.61	15.64	97.50	0.33	21.65	8.4	--
	6-7	84.00	23.00	9.00	0.47	2.61	14.23	97.50	0.79	21.00	8.3	--
	7-8	106.00	23.00	13.00	0.60	2.09	16.21	125.00	0.61	25.00	8.3	--

Appendix Table 21:

Locations of Water Sampling Stations in Panoche Water District

Mendota-Crows Landing Return Flow Group

1975-76

No.	Sampling ID	Sampling location (Township, range and section)	Sample Description
1	PWD-1	12S11E11	Delta Mendota Canal water sample from Lift #1 at Orleans.
2	PWD-2	12S11E23	Water sample from the canal at Lift #4 along Orleans.
3	PWD-3	13S11E2	California Aqueduct water sample from turnout #1 at Orleans.
4	PWD-4T	12S12E32	Tomato field, southwest corner inlet. Water sample along Herndon.
5	PWD-5T	12S12E32	Tomato field, southeast corner. Mixture of Canal and recycled water, along Herndon.
6	PWD-6T	12S12E32	Tomato field, southeast corner. Water sample from the Canal at Herndon.
7	PWD-7T	12S12E32	Tomato field, southeast corner, water sample from recycling water sump, along Herndon.
8	PWD-8E	12S12E27	Tile drained farm, overall supply. Water sample along Russell Avenue.
9	PWD-9E	12S12E27	Tile drained farm, supply water from the District ditch between Nees and Shepard along Russell Avenue.
10	PWD-10E	12S12E27	Tile drained farm, drain water sample before mixing with District supply along Russell Avenue.
11	PWD-11E	12S12E26	Tile drained farm, water sample from the tile sump in northwest corner of Section 26.
12	PWD-12E	12S12E25	Tile drained farm, water sample from the tile sump in northwest corner of Section 25.
13	PWD-13E	12S12E27	Hammond drain water sample from southeast corner of Section 27 along Nees Avenue.
14*	PWD-14	12S11E11	Drain water sample at the lift pump from corner of Outside Canal and Orleans Avenue.
15*	PWD-15	12S12E17	Drain water sample at the lift pump from corner of Courtney Avenue and Prince Avenue.

*These Stations were added to the sampling program on February 4, 1976.

Appendix Table 22:

Water Flow and Quality Data, Panoche Water District

Mendota-Crows Landing Return Flow Group

November 1975 through March 1977

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
PWD-1 Delta Mendota Canal							
11-05-75	1,212	362	224	12	17	0.18	—
1-07-76	4,120	—	—	—	—	—	—
2-04	9,214	283	189	34	78	0	—
3-03	8,881	340	207	22	32	0.10	—
4-07	4,000	374	227	26	43	0.10	—
5-05	10,377	313	198	39	76	0.10	—
6-02	8,108	380	216	34	76	0.05	—
7-07	11,065	517	300	31	47	0.40	8.0
8-04	6,417	522	312	34	71	0.15	7.9
9-08	1,881	877	512	18	37	0.32	8.4
10-06	3,026	1,151	678	9	11	0.12	7.9
11-03	2,379	694	379	13	13	0.18	8.4
1-05-77	546	—	—	—	—	—	—
2-02	1,396	743	414	19	27	0.05	8.1
3-02	2,133	1,224	686	16	40	0.35	8.1
PWD-2 Supply Canal Life 4							
11-05-75	838	773	456	10	19	0.72	—
1-07-76	1,801	—	—	—	—	—	—
2-04	6,082	911	571	40	84	0.45	—
3-03	7,213	468	278	72	218	0.26	—
4-07	2,691	689	398	16	20	0.58	—
5-05	7,038	538	339	33	57	0.50	—
6-02	5,778	1,086	610	35	72	0.50	—
7-07	7,403	676	379	32	49	0.55	7.9
8-04	4,489	543	323	34	54	0.15	7.9
9-08	974	766	436	15	16	0.60	8.1
10-06	1,519	2,094	1,271	5	6	2.42	8.0
11-03	1,453	719	364	17	23	0.32	8.3
2-02-77	1,203	1,671	1,003	3	2	1.20	8.2
3-02	1,455	1,632	982	18	45	0.90	8.2

Appendix Table 22: (continued)

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
PWD-3 California Aqueduct							
11-05-75	2,533	--	--	--	--	--	--
12-03	4,582	307	182	5	3	0.05	--
1-07-76	6,832	267	172	9	17	0	--
2-04	4,588	319	203	15	18	0	--
3-03	5,846	418	249	14	11	0.05	--
4-07	1,289	398	240	10	7	0.22	--
5-05	3,355	500	303	17	17	0.20	--
6-02	4,122	409	238	51	51	0.05	--
7-07	6,606	393	222	3	4	0.30	8.4
8-04	3,134	389	231	5	12	0.10	8.6
9-08	598	413	241	6	4	0.10	8.2
10-06	1,264	586	333	15	17	0.15	8.0
11-03	2,895	637	403	11	12	0.18	8.4
12-15	8,474	675	384	8	5	0.10	8.0
1-05-77	3,491	880	486	79	112	0.10	8.2
2-02	507	1,317	770	7	4	0.80	8.3
3-02	296	1,688	1,038	3	9	1.35	8.5

Appendix Table 23:

Detailed Water Quality Analysis for Panoche Water District

Mendota-Crows Landing Return Flow Group*

1976–1977

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml	
		meq/l						mg/l								Total	Fecal
PWD-1																	
3-3-76	340	1.40	0.93	0.78	1.36	1.21	0.66	1.867	1.06	0.04	0.76	0.007	1.8	—	—	—	—
6-2	380	1.35	0.83	1.03	1.41	1.66	0.83	1.012	0.67	0.03	0.31	0.002	0.6	10.50	8.0	0	0
9-8	877	4.10	2.20	1.80	2.82	4.21	1.72	2.014	0.75	0.05	1.16	0.054	0.6	8.88	8.4	0	0
PWD-2																	
3-3-76	468	2.15	1.30	0.93	1.57	1.83	1.10	2.260	1.03	0.07	1.15	0.010	2.4	—	—	—	—
6-2	1086	5.80	2.50	2.30	2.71	5.49	2.57	2.283	1.18	0.02	1.08	0.003	4.8	10.80	8.9	0	0
9-8	766	3.50	2.00	1.30	1.67	3.65	1.75	3.115	0.47	0.03	2.60	0.015	1.2	9.25	8.1	0	0
PWD-3																	
3-3-76	418	1.93	1.05	0.93	1.46	1.64	0.88	1.550	0.86	0.04	0.64	0.010	0.6	—	—	—	—
6-2	409	1.98	1.08	0.98	1.67	1.66	0.83	1.336	0.77	0.03	0.53	0.006	2.4	10.80	8.9	0	0
9-8	413	1.80	0.85	0.80	1.51	1.69	0.52	0.823	0.36	0.04	0.41	0.013	0.6	9.25	8.2	0	0
1-5-77	880	4.10	2.30	1.45	1.98	4.29	1.40	5.510	1.35	0.10	4.05	0.013	0.6	10.80	8.2	0	0

*Flow, TDS, turbidity, SS, and B are given in Appendix Table 22 for corresponding Stations.

Appendix Table 24·

Water Flow and Quality Data, Panoche Water District

Mendota-Crows Landing Return Flow Group

November 1975 through March 1977

Date	Monthly flow (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
PWD-8E (Mixed Water)							
11-05-75	473	379	226	6	6	0.10	—
1-07-76	363	—	—	—	—	—	—
2-04	736	268	171	17	15	0	—
3-03	1,304	352	212	17	15	0.05	—
4-07	563	—	—	—	—	—	—
5-05	988	1,075	705	30	44	1.00	—
6-02	681	386	227	13	10	0.05	—
7-07	698	1,776	1,166	92	103	1.92	7.7
8-04	307	1,086	668	30	44	0.80	8.3
9-08	14	3,036	2,006	15	24	3.75	8.3
10-06	753	—	—	—	—	—	—
11-03	550	1,052	646	17	18	0.78	8.5
2-02-77	135	2,303	1,664	9	7	2.25	8.4
3-02	159	—	—	—	—	—	—
PWD-9E (Fresh Water)							
11-03-75	440	357	213	6	7	0.08	—
1-07-76	420	—	—	—	—	—	—
2-04	631	255	174	13	16	0	—
3-03	975	353	217	15	12	0.05	—
4-07	439	—	—	—	—	—	—
5-05	721	287	183	30	49	0.10	—
6-02	273	375	229	14	13	0.10	—
7-07	280	434	263	70	88	0.35	8.3
8-04	177	841	473	19	30	0.24	8.9
10-06	456	—	—	—	—	—	—
11-03	354	652	369	8	8	0.22	8.4
2-02-77	0	2,879	1,973	8	3	3.00	8.4

Appendix Table 24: (continued)

Date	Monthly flow (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	pH
PWD-10E (Drain Water)							
11-05-75	33	1,545	997	44	74	1.84	—
1-07-76	143	—	—	—	—	—	—
2-04	85	1,700	1,188	140	206	2.10	—
3-03	329	1,822	1,206	70	97	2.00	—
4-07	124	—	—	—	—	—	—
5-05	267	1,678	1,136	155	284	1.75	—
6-02	408	2,595	1,757	9	16	3.15	—
7-07	418	2,298	1,484	140	280	2.70	7.2
8-04	130	1,630	1,061	110	218	1.55	7.6
9-08	14	3,600	2,756	87	169	4.56	8.3
10-06	297	—	—	—	—	—	—
11-03	196	2,393	1,620	37	53	0.22	8.4
1-05-77	0	2,728	1,800	135	278	2.65	8.0
2-02	135	3,689	2,583	120	206	4.75	8.3
3-02	159	—	—	—	—	—	—
PWD-11E (Tile Sump)							
11-05-75	13	8,644	6,830	38	128	16.00	—
12-03	21	10,430	8,534	2	4	24.65	—
1-07-76	19	11,589	9,366	2	5	24.10	—
2-04	36	8,793	7,298	8	28	18.70	—
3-03	30	9,808	7,487	8	3	17.30	—
4-07	25	9,903	7,775	7	5	20.58	—
5-05	39	9,259	7,543	8	6	17.10	—
6-02	39	9,762	7,808	2	2	17.85	—
7-07	21	10,250	8,189	2	4	21.30	7.5
8-04	18	10,643	8,662	2	4	25.60	7.4
9-08	8	13,263	10,684	0	2	25.12	7.8
10-06	6	16,823	12,553	2	14	32.90	7.4
11-03	23	11,503	9,236	2	1	19.05	8.1
12-15	8	13,906	11,093	2	6	25.80	7.5
1-05-77	8	13,966	9,888	3	11	24.42	7.8
2-02	14	11,018	8,394	2	9	17.10	8.1
3-02	21	11,939	9,359	1	11	22.00	8.0

Appendix Table 24: (continued)

Date	Monthly flow (ac-ft)	EC (umhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	pH
[illegible] (Tile Sump)							
11-03-75	14	9,444	6,928	2	75	10.00	--
12-03	8	10,327	8,606	3	2	13.60	--
1-07-76	5	10,865	8,047	2	2	10.40	--
2-04	28	9,808	8,083	8	9	13.00	--
3-03	98	6,296	4,351	7	36	6.15	--
4-07	51	8,486	6,425	7	7	9.37	--
5-05	43	8,328	6,678	8	7	9.95	--
6-02	36	9,500	7,309	6	3	10.12	--
7-07	16	10,353	7,769	1	15	6.50	7.3
8-04	9	10,430	8,280	0	1	13.52	7.4
9-08	2	9,981	6,807	0	2	12.55	7.4
10-06	36	8,148	6,212	2	39	9.80	7.3
11-03	85	6,966	5,360	2	11	7.27	8.1
12-15	26	8,741	6,062	2	26	9.80	7.7
1-05-77	26	—	—	—	—	—	—
2-02	26	9,138	7,056	2	9	8.60	7.9
3-02	29	9,790	7,577	1	16	11.20	8.1
[illegible] ([illegible] Drain)							
11-05-75	0	4,250	3,095	110	258	7.00	--
12-03	0	1,630	805	125	406	2.60	--
1-07-76	2	1,159	777	265	660	1.50	--
2-04	0	2,060	1,400	72	128	2.75	--
3-03	36	1,789	1,182	-215	267	2.10	--
4-07	1	3,663	2,873	215	536	5.68	--
5-05	30	3,333	2,412	190	669	4.45	--
6-02	3	2,333	1,713	385	935	3.12	--
7-07	66	4,659	3,260	245	263	5.92	8.0
8-04	2	1,630	1,007	590	1,381	1.50	7.5
9-08	0	3,603	170	2,545	704	4.56	7.6
10-06	16	3,779	2,842	390	1,266	5.52	7.6
11-03	1	3,322	2,423	160	232	4.30	8.6
12-15	0	2,448	1,666	61	908	3.60	7.8
1-05-77	0	2,606	1,721	160	266	2.15	7.9
2-02	2	4,906	3,686	320	981	6.92	8.1
3-02	85	6,330	4,922	17	62	9.50	8.0

Appendix Table 25:

Detailed Water Quality Analysis for Tile Drained Farm, Patterson Water District

Patterson-Crows Landing Return Flow Group*

1976-1977

Date	EC (umhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	Coliform/100 ml Total	Coliform/100 ml Fecal
		meq/l						mg/l									
PWD-98 (Mixed Water)																	
3-3-76	350	1.33	0.95	0.83	1.41	1.21	0.76	1.008	0.78	0.06	0.06	0.089	0.6	—	—	—	—
6-2	384	1.88	0.75	1.03	1.41	1.91	0.66	1.036	0.76	0.06	0.23	0.094	0.6	11.20	8.7	0	0
9-8	2036	16.25	0.75	3.75	2.60	11.16	10.00	17.610	0.73	0.17	15.65	0.125	0.6	9.12	8.5	0	400
PWD-99 (Fresh Water)																	
3-3-76	353	1.35	0.98	0.83	1.36	1.26	0.76	1.768	0.87	0.03	0.06	0.089	0.8	—	—	—	—
6-2	375	1.98	0.75	0.98	1.31	1.77	0.64	0.864	0.57	0.03	0.26	0.094	1.0	10.40	8.9	0	0
PWD-110 (Drain Water)																	
3-3-76	1882	10.00	5.00	2.50	2.01	4.49	8.00	11.930	1.53	0.17	10.10	0.130	0.6	—	—	—	—
6-2	2185	15.00	7.00	4.50	2.00	9.49	15.25	17.930	1.35	0.05	15.50	0.170	1.2	10.80	8.0	0	0
9-8	3600	24.50	10.00	6.50	3.03	15.65	21.50	25.130	0.93	0.17	23.80	0.205	0.6	9.00	8.1	0	4000
1-5-77	2728	15.75	8.50	3.75	2.71	9.48	15.90	15.120	1.49	0.01	13.50	0.115	0.6	10.80	8.0	0	0
PWD-115 (Tile Sump)																	
3-3-76	9800	16.50	27.50	17.00	4.70	44.41	46.00	41.103	1.08	0.02	40.00	0.084	0.6	—	—	—	—
6-2	9762	72.00	21.00	21.50	4.50	47.52	66.00	48.882	0.88	0.00	48.00	0.002	0.6	11.40	7.6	0	0
9-8	13051	110.00	30.00	23.00	4.06	70.86	83.10	76.858	0.70	0.01	76.00	0.048	1.2	9.12	7.8	0	0
1-5-77	12966	106.40	28.00	22.25	4.47	52.07	98.03	85.698	1.61	0.02	84.00	0.084	0.6	11.20	7.8	0	0
PWD-121 (Tile Sump)																	
3-3-76	6200	40.00	19.50	10.50	4.81	23.87	41.40	23.746	1.28	0.02	22.40	0.024	1.0	—	—	—	—
6-2	9300	73.00	25.00	17.50	5.83	46.39	63.33	27.788	0.90	0.00	28.80	0.084	1.8	11.40	7.8	0	0
9-8	9981	72.00	28.00	21.00	5.22	48.32	64.80	36.520	0.48	0.02	36.00	0.028	0.6	9.00	7.6	0	0
PWD-130 (Hammond Drain)																	
3-3-76	1788	8.75	5.50	2.75	2.08	5.78	9.25	13.616	2.28	0.14	11.00	0.116	0.6	—	—	—	—
6-2	2533	13.75	7.75	5.00	2.50	8.25	15.50	28.475	5.22	2.00	21.00	0.275	0.6	11.60	8.1	0	1600
9-8	3603	23.50	11.00	6.50	3.24	11.98	22.80	27.025	1.70	0.10	25.10	0.625	6.2	9.16	7.6	0	>1600
1-5-77	2686	14.00	8.50	4.00	2.71	8.58	14.20	18.340	1.68	0.44	16.50	0.163	1.0	11.70	7.8	0	0

*Flow, TDS, turbidity, SS, and B are given in Appendix Table 26 for the corresponding Stations.

Appendix Table 26:

Water Quality Data, Panoche Water District
Mendota-Crows Landing Return Flow Group
February 1976 through March 1977

Date	EC (mmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	pH
PWD-14 Northside Drain						
2-4-76	3,000	2,156	78	122	4.70	—
3-3	3,312	2,247	57	112	4.80	—
4-7	3,129	1,964	18	107	4.08	—
5-5	4,717	3,306	26	45	7.60	—
6-2	4,586	3,211	245	623	6.80	—
7-7	3,087	1,991	28	44	4.12	7.85
8-4	2,608	1,738	30	43	3.43	8.3
9-8	2,442	1,639	16	29	4.70	8.3
10-6	4,498	3,207	8	19	7.35	7.8
11-3	2,177	1,353	62	90	2.42	8.5
12-13	3,839	2,617	30	34	5.40	7.6
2-3-77	4,743	3,268	200	435	6.52	7.5
3-2	4,707	3,335	93	467	5.73	8.1
PWD-13 Courtney Drain						
2-4-76	1,889	1,319	150	215	2.80	—
3-3	2,761	1,837	75	313	4.45	—
4-7	3,342	2,415	45	116	4.61	—
5-5	1,916	1,217	400	780	2.85	—
6-2	3,129	2,088	82	196	3.10	—
7-7	3,441	2,432	76	174	3.56	8.3
8-4	2,730	1,813	275	654	4.19	7.8
9-8	3,211	2,293	88	208	3.45	8.3
10-6	3,752	2,330	88	281	6.72	7.9
11-3	3,566	2,436	24	49	6.66	8.2
12-13	3,263	2,136	21	32	5.06	8.1
1-5-77	3,944	2,381	17	21	5.98	8.3
2-2	3,860	2,666	11	4	6.40	8.2
3-2	3,653	2,493	34	108	5.48	8.1

Appendix Table 27:

Detailed Water Quality Analysis for Tile Drained Farm

Panoche Water District, Mendota-Crows Landing Return Flow Group

Date	EC (mmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	Coliform/100 ml	
		←		meq/ℓ			→	←			mg/ℓ			→		Total	Fecal
PWD-14 Northside Drain																	
3-3-76	3,312	16.50	12.75	5.25	2.51	15.96	17.00	25.808	1.30	0.10	24.4	0.008	0.6	—	—	—	—
6-2	4,586	26.50	16.25	8.25	2.92	23.57	24.67	26.817	2.31	0.39	24.0	0.117	2.4	12.00	7.9	0	100
9-8	2,462	13.10	9.50	4.50	2.82	12.26	10.75	13.406	0.21	0.09	13.0	0.106	4.8	9.12	8.3	0	0
PWD-15 Courtney Drain																	
3-3-76	2,742	14.00	10.00	3.50	2.82	12.86	11.50	29.722	1.06	0.04	28.6	0.022	0.6	—	—	—	—
6-2	3,129	16.75	10.62	3.75	2.92	14.11	13.75	78.122	1.09	0.01	77.0	0.022	0.6	11.50	8.1	0	0
9-8	3,211	19.00	12.01	5.50	3.13	17.05	15.00	26.359	0.27	0.03	26.0	0.059	4.8	9.12	8.3	100	100
1-5-77	3,944	22.00	14.50	5.50	3.34	17.59	18.50	28.060	0.94	0.01	27.0	0.114	3.0	11.20	8.2	0	100

Apendix Table 28:

Location of Soil Sampling Sites in Panoche Water District, 1976.

No.	Sampling Date	Sample I.D.	Sampling Location (township, range and section)	Sampling Depth, ft.	Crop
1	10-13	PWD-S21	12S11E1	9	Wheat
2	10-13	PWD-S22	12S12E7	11	Cotton
3	10-13	PWD-S23	12S12E20	7	Beans
4	10-14	PWD-S24	12S11E23	16	Cotton
5	10-14	PWD-S25	12S11E25	22	Melons
6	10-14	PWD-S26	12S11E36	27	Tomato
7	10-14	PWD-S27	12S12E31	21	Tomato
8	10-14	PWD-S28	12S12E32	18	Melons
9	10-15	PWD-S29	13S12E8	16	Tomato
10	10-15	PWD-S30	13S12E22	24	Melons
11	10-15	PWD-S31	13S12E15	10	Cotton
12	10-15	PWD-S32	13S12E12	19	Cotton
13	10-15	PWD-S33	13S12E18	25	Tomato
14	10-15	PWD-S34	12S12E35	17	Tomato
15	10-16	PWD-S35	13S12E3	15	Cotton
16	10-16	PWD-S36	13S13E5	11	Cotton

Appendix Table 29:

Soil Analyses in Panoche Drainage District

1976

Location	Depth (ft)	Saturation percentage	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S21	0-½	43	10.00	64.7	30.0	1.50	5.44	1.15
	½-1	43	14.29	102.3	42.0	4.00	7.77	1.39
	1-2	41	13.16	66.5	90.0	10.00	6.96	2.20
	2-3	38	14.50	91.2	66.0	7.50	6.96	0.89
	3-4	35	15.15	102.8	66.0	7.50	6.79	0.50
	4-5	38	17.24	125.0	66.0	8.40	8.28	0.38
	5-6	49	14.29	102.2	54.0	8.50	8.93	1.48
	6-7	53	11.11	63.6	66.0	10.00	7.47	2.98
	7-8	53	9.61	45.3	70.0	9.10	6.46	8.46
	8-9	60	10.42	57.9	62.0	8.50	8.00	18.54
PWD S22	0-½	50	3.33	6.1	24.0	7.00	2.13	1.63
	½-1	50	3.42	5.0	28.0	5.80	2.19	1.12
	1-2	61	2.94	6.2	16.0	10.50	2.31	1.32
	2-3	80	2.91	7.2	17.8	16.20	2.98	1.51
	3-4	60	3.62	9.5	27.5	13.80	2.78	1.98
	4-5	43	4.63	6.7	55.0	5.05	2.52	44.14
	5-6	39	5.26	10.6	58.0	7.20	2.61	34.83
	6-7	44	5.68	11.0	64.0	9.00	3.18	27.86
	7-8	39	6.94	13.0	82.0	12.00	3.45	7.26
	8-9	43	8.77	22.2	95.0	17.50	4.77	8.96
	9-10	55	8.93	23.4	90.0	18.50	6.29	19.87
	10-11	49	9.80	28.3	101.3	21.00	6.12	19.88
PWD S23	0-½	55	1.16	3.2	5.6	1.22	0.82	0.67
	½-1	58	1.96	8.9	6.0	1.04	1.44	0.60
	1-2	85	3.52	2.6	50.0	3.10	3.83	2.32
	2-3	54	3.70	2.7	50.0	3.42	2.55	5.69
	3-4	59	5.10	8.6	58.0	6.06	3.84	2.73
	4-5	60	3.38	10.6	22.0	5.52	2.60	1.43
	5-6	64	2.56	8.8	16.2	4.48	2.09	1.39
	6-7	68	2.00	5.4	12.5	3.50	1.73	1.05
PWD S24	0-½	55	1.43	5.9	5.8	0.88	1.01	0.38
	½-1	58	0.86	3.4	2.8	0.82	0.63	0.33
	1-2	55	0.49	1.2	1.8	0.65	0.34	0.40
	2-3	63	0.43	0.9	1.7	0.60	0.34	0.41
	3-4	49	0.53	1.2	2.1	0.65	0.33	0.28
	4-5	45	0.86	3.6	3.2	0.52	0.50	0.15
	5-6	41	0.88	3.7	3.0	0.52	0.47	0.31
	6-7	54	0.56	1.6	2.1	0.52	0.39	0.38
	7-8	44	0.64	2.4	2.1	0.60	0.36	0.29
	8-9	38	0.66	2.4	2.2	0.65	0.32	0.29
	9-10	46	0.65	2.0	2.6	0.70	0.39	0.19
	10-11	48	0.68	2.4	2.4	0.62	0.41	0.38
	11-12	58	0.62	1.7	2.4	0.60	0.46	0.15
	12-13	50	0.74	2.2	3.0	0.75	0.47	0.83
	13-14	48	0.69	1.8	3.2	0.80	0.42	0.53
	14-15	46	0.69	2.3	3.3	0.60	0.41	0.40
	15-16	49	0.74	2.5	3.0	0.60	0.46	0.40

Appendix Table 29: (continued)

Location	Depth (ft)	Saturation percentage	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S25	0-½	53	1.03	2.9	3.3	0.48	0.69	0.40
	½-1	51	0.88	2.4	3.0	0.52	0.58	0.40
	1-2	51	0.53	1.5	1.9	0.52	0.35	0.33
	2-3	49	0.66	1.8	2.2	0.65	0.41	0.21
	3-4	40	0.66	1.9	2.6	0.70	0.34	0.22
	4-5	40	0.76	1.5	3.5	1.05	0.39	0.33
	5-6	43	1.03	1.4	6.2	1.72	0.57	0.15
	6-7	31	1.27	1.8	9.3	2.10	0.51	0.19
	7-8	29	1.42	4.7	7.5	2.45	0.52	0.14
	8-9	30	1.62	7.1	6.0	2.40	0.62	0.21
	9-10	44	1.81	8.1	8.0	1.90	1.01	0.57
	10-11	43	1.27	5.1	5.2	1.10	0.69	0.05
	11-12	36	1.01	4.5	3.0	0.75	0.47	0.12
	12-13	41	0.82	3.5	2.1	0.70	0.43	0.28
	13-14	55	0.77	2.8	2.2	1.10	0.54	0.22
	14-15	50	0.86	3.2	2.2	1.60	0.55	0.24
	15-16	54	0.80	2.8	2.0	2.10	0.55	0.33
	16-17	51	0.85	3.2	2.8	2.20	0.56	0.36
	17-18	51	0.61	1.5	2.6	2.00	0.40	0.34
	18-19	49	0.61	1.4	2.7	1.75	0.38	0.29
	19-20	36	0.72	2.2	2.8	1.75	0.33	0.26
	20-21	39	0.83	3.0	2.5	1.40	0.41	0.22
	21-22	53	0.89	3.2	2.0	1.40	0.60	0.31
PWD S26	0-½	52	2.56	6.7	7.4	0.10	1.69	0.17
	½-1	51	3.50	10.1	7.8	0.05	2.30	0.34
	1-2	55	0.67	1.5	1.0	0.22	0.47	0.17
	2-3	46	0.40	0.7	1.4	0.22	0.24	0.29
	3-4	40	0.41	0.7	1.5	0.22	0.21	0.29
	4-5	49	0.43	0.9	1.6	0.28	0.27	0.34
	5-6	44	0.45	1.0	1.6	0.30	0.25	0.22
	6-7	39	0.48	1.1	1.6	0.40	0.24	0.24
	7-8	41	0.44	0.9	1.7	0.42	0.23	0.29
	8-9	43	0.47	1.0	1.9	0.46	0.26	0.21
	9-10	48	0.52	1.1	1.9	0.52	0.32	0.29
	10-11	43	0.59	1.2	2.0	0.52	0.32	0.14
	11-12	40	0.61	1.1	2.2	0.52	0.31	0.19
	12-13	43	0.75	1.1	3.3	0.75	0.41	0.21
	13-14	40	0.56	0.7	2.2	0.70	0.29	0.07
	14-15	39	0.75	1.5	2.8	0.88	0.37	0.29
	15-16	35	0.77	1.6	2.8	0.75	0.34	0.28
	16-17	35	0.75	1.7	2.1	0.80	0.34	0.14
	17-18	36	0.80	2.0	2.2	0.80	0.37	0.21
	18-19	35	0.78	2.1	2.4	0.85	0.35	0.12
	19-20	35	0.80	2.0	2.6	0.96	0.36	0.28
	20-21	33	0.71	1.8	2.4	1.02	0.30	0.21
	21-22	30	0.75	2.0	2.4	1.02	0.29	0.31
	22-23	40	0.76	2.3	2.4	0.96	0.39	0.28
	23-24	40	0.76	2.5	2.4	1.15	0.39	0.22
	24-25	31	0.69	2.0	2.6	1.40	0.28	0.29
	25-26	36	0.73	2.2	2.8	1.50	0.35	0.22
	26-27	30	0.74	1.8	3.2	2.00	0.28	0.22

Appendix Table 29: (continued)

Location	Depth (ft)	Saturation percentage	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S27	0-½	50	1.32	3.0	7.0	1.20	0.84	0.48
	½-1	44	1.02	2.3	5.2	0.90	0.57	0.53
	1-2	53	1.61	3.6	10.8	1.10	1.08	0.50
	2-3	53	2.40	7.2	17.5	1.50	1.61	0.69
	3-4	48	1.78	5.0	13.5	1.25	1.08	0.24
	4-5	55	1.36	3.0	9.8	0.95	0.96	0.07
	5-6	48	0.87	1.6	5.0	0.70	0.53	0.24
	6-7	49	0.72	1.0	4.1	0.70	0.45	0.22
	7-8	45	0.73	1.0	3.9	0.80	0.42	0.14
	8-9	46	0.64	0.8	3.5	0.60	0.38	0.24
	9-10	51	0.87	1.1	5.2	0.65	0.57	0.22
	10-11	41	1.01	1.5	6.2	0.80	0.53	0.31
	11-12	46	1.03	2.0	5.8	0.65	0.61	0.14
	12-13	34	0.97	1.6	5.6	0.60	0.42	0.19
	13-14	34	1.03	1.8	5.6	0.80	0.45	0.43
	14-15	36	1.05	2.9	4.4	0.80	0.49	0.17
	15-16	35	1.00	2.0	4.6	0.85	0.45	0.17
	16-17	30	0.90	2.4	4.4	0.80	0.35	0.21
	17-18	30	1.03	1.6	5.0	0.85	0.40	0.14
	18-19	30	1.61	5.9	9.8	1.25	0.62	0.29
	19-20	35	2.34	8.0	13.5	2.80	1.05	0.14
	20-21	27	2.90	10.0	16.0	3.00	1.00	0.02
PWD S28	0-½	43	3.06	5.3	6.0	0.10	1.66	0.31
	½-1	44	1.52	3.1	2.0	0.22	0.85	0.28
	1-2	40	0.41	0.4	1.1	0.25	0.21	0.28
	2-3	35	0.46	0.4	1.4	0.22	0.21	0.17
	3-4	38	0.38	0.4	1.6	0.25	0.18	0.15
	4-5	38	0.38	0.3	1.4	0.25	0.18	0.09
	5-6	44	0.42	0.5	1.8	0.35	0.24	0.17
	6-7	40	0.44	0.5	1.8	0.50	0.23	0.19
	7-8	45	0.56	0.6	2.5	0.50	0.32	0.26
	8-9	41	0.70	0.9	2.9	0.72	0.37	0.22
	9-10	41	0.70	1.3	2.8	0.85	0.37	0.19
	10-11	36	0.80	1.7	3.2	1.02	0.37	0.10
	11-12	41	0.74	1.6	3.2	1.12	0.39	0.12
	12-13	43	0.84	2.0	2.1	1.20	0.46	0.29
	13-14	39	0.91	2.2	4.3	1.05	0.45	0.19
	14-15	39	1.11	3.3	4.5	1.12	0.55	0.19
	15-16	41	1.17	3.4	5.4	1.05	0.62	0.22
	16-17	43	1.09	3.3	5.0	1.20	0.59	0.29
	17-18	38	1.29	3.8	6.6	1.25	0.62	0.22

Appendix Table 29: (continued)

Location	Depth (ft)	Saturation percentage	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S29	0-½	49	4.90	10.1	26.0	0.66	3.06	0.71
	½-1	48	3.31	11.5	7.0	0.50	2.01	0.46
	1-2	48	1.14	3.2	5.0	0.95	0.69	0.48
	2-3	45	1.14	3.1	5.4	1.25	0.66	0.50
	3-4	54	1.66	12.2	7.5	1.60	1.14	0.52
	4-5	54	2.80	13.2	12.5	2.35	1.93	0.53
	5-6	51	2.58	11.9	11.5	2.72	1.69	0.48
	6-7	46	1.81	7.4	8.8	3.36	1.07	0.57
	7-8	49	1.63	6.1	8.0	3.76	1.02	0.29
	8-9	58	1.53	5.1	8.3	3.63	1.13	2.01
	9-10	56	1.31	3.7	8.0	3.25	0.94	0.19
	10-11	51	1.53	4.4	8.0	2.80	1.00	0.40
	11-12	38	1.27	4.5	5.0	2.55	0.61	0.22
	12-13	40	1.68	4.7	7.4	1.65	0.86	0.03
	13-14	41	1.31	4.4	5.4	1.62	0.69	0.34
	14-15	38	1.66	6.7	6.2	1.42	0.80	0.29
	15-16	38	1.85	2.4	9.5	1.70	0.89	0.48
PWD S30	0-½	64	2.45	2.6	5.0	0.22	2.00	0.40
	½-1	60	2.65	2.7	5.0	0.25	2.04	0.48
	1-2	60	1.40	1.6	3.7	0.22	1.08	0.52
	2-3	60	1.06	1.5	3.3	0.32	0.81	0.48
	3-4	58	1.29	3.0	3.7	0.40	0.95	0.46
	4-5	45	2.15	5.4	6.8	0.50	1.24	0.19
	5-6	37	1.32	2.5	2.6	0.22	0.63	0.17
	6-7	38	1.25	4.0	2.5	0.40	0.61	0.17
	7-8	44	1.53	5.3	5.2	0.70	0.86	0.46
	8-9	33	0.49	1.1	1.3	0.32	0.21	1.48
	9-10	35	0.94	3.4	2.5	0.50	0.42	0.12
	10-11	51	1.11	4.1	2.8	0.35	0.73	0.48
	11-12	36	0.69	1.8	1.4	0.25	0.32	0.33
	12-13	41	0.63	1.2	1.2	0.32	0.33	0.26
	13-14	28	0.54	0.7	1.6	0.22	0.19	0.21
	14-15	33	0.61	0.7	1.8	0.25	0.26	0.17
	15-16	34	0.66	0.9	2.1	0.40	0.29	0.22
	16-17	33	0.65	0.7	2.0	0.35	0.27	0.36
	17-18	36	0.56	0.5	2.1	0.15	0.26	0.22
	18-19	36	0.55	0.5	1.8	0.30	0.25	0.10
	19-20	29	0.58	0.5	1.8	0.25	0.22	0.09
	20-21	45	0.65	0.8	2.4	0.40	0.37	0.36
	21-22	50	0.72	1.0	2.4	0.40	0.46	0.28
	22-23	49	0.65	0.7	2.4	0.70	0.41	0.28
	23-24	50	0.77	0.9	3.5	0.66	0.49	0.40

Appendix Table 29: (continued)

Location	Depth (ft)	Saturation percentage	EC_e (mmhon/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S31	0-½	64	1.64	3.5	4.5	0.40	1.34	0.79
	½-1	61	1.32	1.9	5.0	0.55	1.04	0.72
	1-2	65	0.85	1.3	3.7	0.50	0.71	0.71
	2-3	65	0.95	1.5	5.2	0.55	0.79	0.58
	3-4	58	0.82	1.1	3.9	0.38	0.60	0.71
	4-5	65	0.84	1.0	4.3	0.55	0.70	0.77
	5-6	65	0.91	1.1	4.6	0.82	0.76	0.69
	6-7	69	2.27	1.0	21.5	0.95	2.00	0.91
	7-8	63	4.24	1.0	54.0	1.52	3.39	16.55
	8-9	70	4.62	1.1	58.0	1.52	4.14	25.70
	9-10	58	5.16	1.2	66.0	2.20	3.80	32.16
PWD S32	0-½	53	1.40	1.6	8.0	0.35	0.94	0.45
	½-1	55	1.02	1.6	3.7	0.22	0.72	0.45
	1-2	61	0.76	1.4	3.0	0.40	0.60	0.62
	2-3	68	0.77	1.3	4.1	0.43	0.67	0.72
	3-4	58	1.09	1.6	4.4	0.55	0.80	0.69
	4-5	60	1.04	1.5	4.6	0.60	0.80	0.77
	5-6	55	1.09	1.6	4.4	0.66	0.77	0.58
	6-7	51	1.21	2.1	5.5	0.72	0.79	0.40
	7-8	51	1.21	2.3	5.3	0.66	0.79	0.48
	8-9	53	1.50	3.4	7.8	0.70	1.01	0.50
	9-10	58	3.55	4.8	41.0	0.78	2.61	0.93
	10-11	69	3.69	6.4	43.0	0.72	3.25	97.04
	11-12	66	3.67	6.9	44.0	0.78	3.11	52.74
	12-13	68	4.07	3.0	52.0	0.90	3.52	56.86
	13-14	61	4.09	2.0	52.0	1.12	3.21	43.29
	14-15	58	3.15	1.9	52.0	1.00	2.32	24.10
	15-16	53	4.57	2.3	56.0	1.40	3.07	12.83
	16-17	61	4.53	2.2	54.0	1.12	3.55	16.67
	17-18	51	4.49	2.5	54.0	1.12	2.95	7.96
	18-19	48	4.45	2.8	52.0	1.00	2.71	8.48
PWD S33	0-½	79	2.53	1.7	23.0	1.30	2.55	1.87
	½-1	66	2.74	2.3	27.0	1.12	2.33	1.74
	1-2	65	1.88	2.0	13.5	1.48	1.56	1.75
	2-3	68	1.82	1.9	11.5	1.65	1.57	1.32
	3-4	54	2.02	1.9	14.5	1.85	1.39	0.52
	4-5	60	5.43	2.1	66.0	2.33	4.17	9.10
	5-6	64	5.49	2.3	68.0	2.46	4.48	45.86
	6-7	61	5.61	3.6	70.0	2.33	4.40	63.14
	7-8	65	5.74	5.3	68.0	2.46	4.78	57.76
	8-9	53	5.88	6.0	68.0	2.72	3.95	34.71
	9-10	59	5.74	7.0	66.0	2.96	4.32	32.03
	10-11	48	6.02	7.0	70.0	3.36	3.66	17.49
	11-12	35	5.61	5.5	68.0	3.36	2.51	10.01
	12-13	36	6.02	5.4	70.0	3.70	2.80	14.12
	13-14	39	6.18	6.5	74.0	4.02	3.07	20.00
	14-15	40	5.15	3.7	66.0	2.98	2.64	29.00
	15-16	38	3.89	1.7	52.0	1.32	1.89	15.57
	16-17	38	4.22	1.3	56.0	1.60	2.03	11.87
	17-18	61	4.62	1.0	62.0	1.60	3.63	60.54
	18-19	53	4.62	0.7	62.0	1.52	3.10	19.33
	19-20	54	4.08	0.8	56.0	1.10	2.81	12.45
	20-21	55	4.45	0.5	60.0	1.24	3.13	13.24
	21-22	48	5.43	0.6	70.0	1.85	3.30	5.62
	22-23	50	5.74	0.4	74.0	2.20	3.67	4.99
	23-24	46	6.50	0.7	84.0	2.60	3.85	9.22
	24-25	35	5.81	0.6	68.0	2.46	2.60	0.21

Appendix Table 29: (continued)

Location	Depth (ft)	Saturation percentage	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S34	0-½	66	2.91	8.0	12.3	1.20	2.47	1.22
	½-1	73	1.90	8.1	8.5	1.00	1.76	1.00
	1-2	75	3.05	7.0	21.0	1.85	2.93	1.93
	2-3	76	7.49	9.4	77.0	2.85	7.32	26.90
	3-4	78	8.82	10.7	88.0	4.02	8.75	55.35
	4-5	75	8.87	11.7	95.0	3.75	8.52	54.82
	5-6	78	8.23	12.0	86.0	3.62	8.16	38.41
	6-7	79	8.23	12.7	90.0	3.90	8.30	35.97
	7-8	70	8.37	15.2	84.0	4.68	7.50	38.05
	8-9	75	8.37	14.9	86.0	4.16	8.04	35.35
	9-10	66	9.50	25.9	86.0	5.28	8.06	38.36
	10-11	68	8.98	21.2	84.0	5.00	7.76	40.13
	11-12	70	10.74	38.6	76.0	5.28	9.62	56.23
	12-13	68	11.49	44.1	84.0	5.70	9.93	40.13
	13-14	69	10.98	41.4	78.0	5.60	9.67	38.92
	14-15	66	12.05	48.7	82.0	6.12	10.23	38.80
	15-16	65	10.98	40.8	82.0	5.75	9.14	38.99
	16-17	66	10.98	30.6	92.5	7.10	9.32	61.70
PWD S35	0-½	58	1.62	2.3	11.5	0.95	1.19	0.07
	½-1	60	1.05	2.1	5.2	0.78	0.81	0.67
	1-2	63	1.28	1.7	6.8	0.90	1.02	0.84
	2-3	48	1.65	3.0	9.3	1.00	1.00	0.83
	3-4	50	1.73	3.3	9.5	0.94	1.11	0.96
	4-5	53	1.70	2.9	10.8	0.94	1.14	0.89
	5-6	56	3.19	2.2	33.0	1.00	2.30	2.48
	6-7	68	4.31	5.1	52.0	1.40	3.72	8.46
	7-8	71	4.10	3.1	50.0	1.05	3.74	16.22
	8-9	66	3.42	3.2	50.0	1.12	2.90	54.49
	9-10	70	3.33	4.8	26.0	1.36	2.98	45.03
	10-11	70	4.24	4.6	37.0	1.50	3.80	41.99
	11-12	68	4.31	5.5	46.0	1.40	3.72	44.53
	12-13	66	4.35	5.3	51.0	1.60	3.69	33.75
	13-14	68	4.39	4.5	50.0	1.60	3.79	35.04
	14-15	94	4.27	2.6	46.0	1.48	5.13	29.57
PWD S36	0-½	81	2.27	4.3	13.0	1.85	2.36	0.96
	½-1	76	4.17	6.2	32.0	2.10	4.07	1.65
	1-2	75	5.10	8.8	46.0	1.25	4.90	2.67
	2-3	75	3.47	9.5	18.5	0.82	3.33	0.79
	3-4	71	3.79	13.9	17.5	0.90	3.46	1.38
	4-5	78	3.52	13.1	18.5	1.20	3.49	1.07
	5-6	75	3.05	13.0	43.0	1.24	4.85	9.92
	6-7	63	5.62	16.6	43.0	1.52	4.50	16.87
	7-8	74	5.00	14.3	43.0	1.30	4.72	19.49
	8-9	69	5.32	15.1	44.0	1.40	4.69	13.71
	9-10	70	5.44	16.7	41.0	1.48	4.87	18.28
	10-11	70	5.10	13.8	46.0	1.52	4.57	26.28

Appendix Table 30:

Water Sample Locations and Description in
Los Banos Wildlife Area
Mendota-Crows Landing Return Flow Group
1976

No.	Sample I.D.	Sample Description
1	LBWA- 1	San Luis Federal Drain at Henry Miller Ave. water sample upstream from bridge.
2	LBWA- 2	San Luis Canal at Henry Miller Ave. water sample above the check structure.
3	LBWA- 3	Sewage slough at Henry Miller Ave. water sample from north side (downstream) of the road.
4	LBWA- 4	Mud Slough inlet to the area just north of Henry Miller Ave. water sample from the downstream end of culvert.
5	LBWA- 5	Boundary drain inlet water sample at the flume.
6	LBWA- 6	San Pedro Canal water sample from the flume.
7	LBWA- 7	Low Lift #2 (water is same as boundary drain, therefore no sample) only quantity measurement.
8	LBWA- 8	West Delta Canal inlet water sample at the recorder station.
9	LBWA- 9	Outflow to Mud Slough from Buttonwillow Lake water sample from lower end of pipes.
10	LBWA-10	Mud Slough at City drain water sample from the check structure (upstream).
11	LBWA-11	San Luis Canal at Ruth Lake Low Lift (water is same as #2) only quantity measurement.
12	LBWA-12	Water sample from the lower Ruth Lake just southeast of Low Lift.
13	LBWA-13	Water sample from field 11 below gooseneck.
14	LBWA-14	Field #37, 38 discharge into Mud Slough.

Appendix Table 31:

Water Flow and Detailed Water Quality Analysis, Los Banos Wildlife Area

Mendota-Crows Landing Return Flow Group

November 1975 through March 1977

Date	Monthly Flow (ac-ft)	EC (µmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml	
							meq/l						mg/l								Total	Fecal
LBWA-1 San Luis Federal Drain																						
11-6-75	-	3,597	2,337	7	19	6.15	-	-	-	-	-	-	1.324	1.06	0.26	0.022	0.002	1.8	8.33	-	0	0
12-4	-	3,893	2,855	10	13	6.80	-	-	-	-	-	-	1.168	0.84	0.21	0.096	0.002	0.6	9.38	-	0	0
1-6-76	-	4,761	3,850	5	7	8.32	-	-	-	-	-	-	2.182	1.10	0.10	0.980	0.002	1.8	8.90	-	0	0
2-6	-	4,287	3,471	11	11	8.30	-	-	-	-	-	-	-	-	-	-	-	-	13.20*	-	-	-
3-6	-	4,322	3,219	10	27	5.92	28.50	4.75	9.50	4.38	15.10	28.13	1.213	1.13	0.07	0.013	0.000	0.6	11.00*	-	0	0
4-8	-	3,449	4,060	13	17	8.32	-	-	-	-	-	-	-	-	-	-	-	-	10.23*	-	-	-
5-6	-	4,717	3,411	16	16	7.80	-	-	-	-	-	-	1.027	0.88	0.12	0.025	0.002	6.0	9.50	-	0	190
6-3	-	3,567	2,470	12	27	5.22	23.50	7.75	7.75	3.34	11.97	26.17	1.348	1.46	0.06	0.044	0.004	0.6	11.50	8.2	0	0
7-6	-	3,555	2,317	9	52	5.17	-	-	-	-	-	-	2.368	2.08	0.16	0.140	0.008	4.2	8.70	8.4	0	0
8-3	-	3,471	2,502	6	61	5.08	-	-	-	-	-	-	2.325	1.90	0.21	0.120	0.001	1.8	9.00	8.8	0	0
9-8	-	2,480	1,726	7	42	2.96	15.50	4.50	6.50	2.40	8.32	15.50	1.161	0.86	0.14	0.135	0.026	3.6	9.00	8.5	0	0
10-7	-	2,833	1,865	8	23	2.86	-	-	-	-	-	-	1.164	0.94	0.11	0.100	0.006	1.8	8.62	7.7	0	0
11-4	-	3,160	2,238	7	8	3.92	-	-	-	-	-	-	1.922	1.85	0.05	0.020	0.002	3.0	8.40	8.3	0	0
12-16	-	4,430	3,365	16	32	3.86	-	-	-	-	-	-	1.354	1.00	0.30	0	0.054	1.8	10.22	8.1	0	100
1-6-77	-	4,456	3,066	11	46	5.55	20.50	13.00	10.00	5.01	14.77	12.30	2.410	1.85	0.10	0.460	0	0.6	10.50	8.2	0	0
2-3	-	6,186	4,811	7	60	6.92	-	-	-	-	-	-	3.060	1.10	1.80	1.110	0.146	0.6	8.76	8.3	0	0
3-3	-	6,095	4,379	10	91	9.26	-	-	-	-	-	-	11.410	1.60	0.80	8.600	0.410	4.8	8.60	8.6	0	0
LBWA-2 San Luis Canal																						
11-6-75	181	1,931	1,213	40	72	2.35	-	-	-	-	-	-	3.373	1.18	0.12	2.000	0.023	1.2	8.47	-	0	0
12-4	13	4,076	2,860	37	45	6.70	-	-	-	-	-	-	8.135	1.11	0.09	6.900	0.035	1.2	9.00	-	200	0
1-6-76	30	3,477	2,448	22	23	5.55	-	-	-	-	-	-	3.542	1.08	0.12	2.700	0.042	2.4	8.98	-	13,000	0
2-6	72	3,081	2,132	32	40	4.40	-	-	-	-	-	-	-	-	-	-	-	-	13.60*	-	-	-
3-6	179	3,490	2,417	42	66	3.00	20.75	10.75	6.00	2.16	23.49	20.60	13.279	1.47	0.13	13.470	0.079	0.6	11.40*	-	0	0
4-8	0	2,866	1,867	44	70	3.12	-	-	-	-	-	-	-	-	-	-	-	-	10.08*	-	-	-
5-6	36	2,967	1,418	33	88	4.35	-	-	-	-	-	-	10.162	0.99	0.21	8.800	0.162	4.8	9.13	-	2,100	600
6-3	29	3,128	2,127	74	34	3.03	20.25	6.30	6.00	2.92	12.96	17.50	11.360	1.32	0.08	9.600	0.080	0.6	11.30	8.0	0	0
7-6	99	2,322	1,581	78	130	3.30	-	-	-	-	-	-	6.206	1.33	0.11	4.600	0.106	2.4	10.00	8.1	0	0
8-3	6	2,745	1,885	65	116	3.00	-	-	-	-	-	-	11.362	1.26	0.16	9.800	0.062	2.4	8.00	8.8	0	0
9-8	142	2,785	1,920	48	84	4.00	16.50	8.50	3.50	4.38	12.26	14.00	7.990	0.61	0.19	7.000	0.190	1.2	9.07	8.3	0	100
10-7	480	1,406	867	180	111	1.65	-	-	-	-	-	-	2.998	0.98	0.12	1.840	0.038	4.2	8.84	7.8	0	0
11-4	58	2,370	1,518	48	62	2.88	-	-	-	-	-	-	3.670	1.05	0.18	1.300	0.023	0.4	8.60	8.6	0	0
12-16	84	3,705	2,712	23	35	4.56	-	-	-	-	-	-	7.610	1.56	0.12	6.400	0.050	0.4	10.22	8.1	2,100	0
1-6-77	0	3,657	2,631	21	38	4.03	26.50	11.00	5.50	3.76	13.56	21.50	10.360	1.98	0.22	7.600	0.140	0.6	10.50	8.2	380	100
2-3	161	4,138	3,009	33	61	5.62	-	-	-	-	-	-	11.080	0.49	0.11	10.000	0.077	0.6	8.36	8.2	0	0
3-3	-	3,871	2,610	36	72	4.10	-	-	-	-	-	-	16.430	1.00	0.30	17.000	0.130	2.4	8.67	8.6	0	0

Date	Monthly flow (ac-ft)	EC (µmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Total N (mg/l)	Organic N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	NO_2-N (mg/l)	BOD (mg/l)	DO (mg/l)	pH	coliform/100 ml Total	coliform/100 ml Fecal
LBRA-3 Municipal Sewage Effluent																						
11-6-75	6*	2,267	1,310	12	36	2.08	-	-	-	-	-	-	8.603	0.70	7.80	0.076	0.027	3.0	9.00	-	0	0
12-4	6*	2,628	1,616	19	35	2.20	-	-	-	-	-	-	10.226	9.81	0.19	0.066	0.150	13.8	9.50	-	400	100
1-6-76	5*	3,259	2,320	12	3	4.30	-	-	-	-	-	-	12.573	5.85	6.65	0.063	0.010	6.0	8.82	-	1,000	3,700
2-6	5*	2,217	1,389	12	16	1.62	-	-	-	-	-	-	-	-	-	-	-	-	14.00*	-	-	-
3-6	6*	2,329	1,336	22	30	1.78	12.62	5.00	5.00	8.26	10.16	4.60	55.065	65.30	9.70	0.013	0.032	6.0	11.90*	-	0	25,000
4-8	2*	3,138	2,181	10	10	2.65	-	-	-	-	-	-	-	-	-	-	-	-	10.63*	-	-	-
5-6	2*	2,890	1,903	25	68	2.50	-	-	-	-	-	-	16.676	13.07	1.63	0.126	0.050	23.1	9.30	-	0	2,200
6-3	1*	3,129	2,030	5	10	2.68	17.50	7.25	8.25	7.93	13.32	12.50	5.828	3.38	2.32	0.120	0.008	0.6	11.50	8.1	0	300
7-8	1*	3,395	2,372	6	7	2.70	-	-	-	-	-	-	2.021	1.38	0.52	0.100	0.031	6.8	8.80	7.8	0	2,800
8-5	1*	3,677	2,365	5	7	2.80	-	-	-	-	-	-	6.936	4.48	1.96	0.126	0.012	1.2	9.40	7.9	0	0
9-9	2*	3,977	2,747	7	14	3.60	25.00	9.00	10.50	8.16	20.15	17.00	7.406	2.65	4.75	0.170	0.036	1.2	8.98	8.0	0	700
10-7	2*	3,065	1,777	7	7	2.36	-	-	-	-	-	-	9.582	2.80	6.70	0.074	0.008	1.8	8.57	8.2	0	100
11-4	3*	2,865	1,782	16	13	2.62	-	-	-	-	-	-	14.610	10.82	3.86	0.080	0.025	4.2	9.78	8.4	0	100
12-16	3*	3,263	2,135	27	46	3.00	-	-	-	-	-	-	16.150	6.60	9.40	0.130	0.017	5.4	10.33	7.7	0	100
1-6-77	3*	2,730	1,618	86	60	1.90	16.25	5.50	5.25	10.23	12.18	5.70	40.280	32.80	5.20	2.200	0.084	34.2	10.80	7.7	0	0
2-3	3*	4,074	2,784	11	11	4.08	-	-	-	-	-	-	13.110	4.10	8.90	0.088	0.017	3.6	8.80	8.2	0	200
3-3	-	3,188	2,098	6	35	2.25	-	-	-	-	-	-	15.610	4.50	11.00	0.092	0.013	0.6	8.50	8.2	0	0
LBRA-4 Mud Slough Inlet																						
11-6-75	-	1,288	781	23	45	0.96	-	-	-	-	-	-	1.916	1.78	0.12	0.012	0.002	2.4	9.00	-	100	0
12-4	-	1,736	1,070	14	21	1.70	-	-	-	-	-	-	1.066	0.80	0.20	0.060	0.006	3.0	9.71	-	0	0
1-8-76	-	2,483	1,665	16	18	2.75	-	-	-	-	-	-	1.967	1.66	0.26	0.042	0.005	5.4	8.67	-	100	0
2-6	-	3,188	2,297	25	31	3.86	-	-	-	-	-	-	-	-	-	-	-	-	14.00*	-	-	-
3-4	-	3,923	2,761	36	77	5.30	26.50	9.75	7.50	4.38	18.21	21.00	3.367	1.97	0.13	0.250	0.017	0.6	11.90*	-	0	0
4-8	-	4,920	3,398	47	86	6.12	-	-	-	-	-	-	-	-	-	-	-	-	10.50*	-	-	-
5-6	-	4,651	3,216	31	53	5.85	-	-	-	-	-	-	1.510	1.47	0.03	0.010	0.000	5.4	9.22	-	0	0
6-3	-	3,432	2,298	66	107	3.65	21.00	6.50	7.25	3.55	16.92	15.50	3.366	2.72	0.58	0.060	0.006	4.2	10.80	8.2	0	0
7-8	-	2,363	1,485	66	101	2.32	-	-	-	-	-	-	2.808	2.36	0.14	0.100	0.008	3.0	8.60	8.6	0	0
8-5	-	2,006	1,268	57	85	1.60	-	-	-	-	-	-	2.878	2.71	0.09	0.056	0.002	5.4	9.70	8.8	0	0
9-9	-	3,096	2,155	38	69	4.70	19.00	8.50	6.50	4.18	14.24	16.50	2.162	1.67	0.33	0.185	0.007	4.2	8.88	8.3	0	0
10-7	-	3,205	2,068	69	73	4.70	-	-	-	-	-	-	2.587	2.36	0.16	0.080	0.007	6.6	8.62	7.4	0	0
11-4	-	1,563	899	40	59	1.13	-	-	-	-	-	-	1.720	1.60	0.10	0.020	0.002	2.4	8.97	8.9	0	0
12-16	-	1,660	1,196	10	35	1.44	-	-	-	-	-	-	1.350	1.06	0.24	0	0.050	1.8	10.00	8.2	0	0
1-6-77	-	2,319	1,613	23	27	1.83	15.50	6.00	4.50	1.80	9.93	11.00	1.650	1.30	0.40	0.066	0.003	1.2	10.33	8.6	0	0
2-3	-	3,367	2,280	33	63	3.80	-	-	-	-	-	-	2.670	1.32	0.28	0.656	0.015	1.8	8.33	8.3	0	0
3-3	-	4,638	3,371	20	63	5.66	-	-	-	-	-	-	19.000	2.26	1.28	14.100	0.220	0.6	8.86	8.8	0	0

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	Na	Ca	Mg	HCO$_3$	Cl	SO$_4$	Total N	Organic N	NH$_4$-N	NO$_3$-N	NO$_2$-N	BOD	DO	pH	coliform/100 ml Total	Fecal
							meq/ℓ						mg/ℓ									
LBWk-5 Boundary Drain																						
11-6-75	1,740	1,605	919	32	56	0.65	-	-	-	-	-	-	1.286	0.94	0.16	0.180	0.006	1.8	9.33	-	300	400
12-4	1,302	2,086	1,176	31	33	0.90	-	-	-	-	-	-	0.971	0.65	0.05	0.264	0.007	3.6	9.43	-	0	0
2-6-76	3,610	1,759	1,100	24	38	0.88	-	-	-	-	-	-	-	-	-	-	-	-	13.20*	-	-	-
3-4	3,610	1,629	955	21	26	0.40	8.25	4.00	2.75	2.92	8.75	3.90	3.893	1.32	0.18	2.300	0.093	3.0	11.60*	-	0	0
4-8	2,820	1,371	761	48	89	0.45	-	-	-	-	-	-	-	-	-	-	-	-	10.84*	-	-	-
5-6	2,294	1,211	672	38	126	0.30	-	-	-	-	-	-	1.388	0.91	0.19	0.268	0.020	3.0	10.00	-	0	100
6-3	2,970	1,267	726	77	166	0.45	6.80	2.40	2.70	6.67	3.45	12.83	2.172	1.72	0.08	0.360	0.012	7.8	11.40	8.0	800	200
7-8	2,077	1,151	702	80	202	0.45	-	-	-	-	-	-	3.495	1.56	0.24	1.600	0.095	3.0	8.60	7.6	0	100
8-5	3,069	1,199	696	68	154	0.22	-	-	-	-	-	-	4.068	1.96	0.96	1.060	0.108	0.6	8.80	7.7	0	100
9-9	2,730	1,332	783	47	97	0.30	7.00	3.20	2.90	7.14	3.40	13.57	2.293	0.46	1.06	0.718	0.075	3.0	8.75	8.1	400	0
10-7	3,069	1,450	813	28	65	0.36	-	-	-	-	-	-	1.053	0.24	0.21	0.580	0.023	1.2	9.16	7.9	1,200	200
11-4	2,790	1,387	796	33	52	0.40	-	-	-	-	-	-	1.810	0.74	0.26	0.780	0.025	1.2	8.77	8.5	0	100
12-16	-	2,576	1,436	27	129	0.50	-	-	-	-	-	-	1.500	0.72	0.58	0.100	0.100	6.0	10.33	7.6	0	100
1-6-77	1,381	2,834	1,571	42	51	1.12	16.75	6.00	5.25	6.80	14.10	8.75	1.770	1.38	0.07	0.310	0.008	0.6	11.00	8.4	1,400	200
2-3	1,428	2,533	1,597	24	37	1.60	-	-	-	-	-	-	1.930	0.76	0.36	0.810	0.013	6.6	8.78	8.3	300	200
3-3	2,728	2,757	1,737	24	43	1.75	-	-	-	-	-	-	6.230	1.08	0.42	4.550	0.175	0.6	8.74	8.1	0	0
LwGh-6 San Pedro Canal																						
11-6-75	816	646	372	37	64	0.30	-	-	-	-	-	-	1.063	0.63	0.07	0.360	0.003	1.2	9.33	-	300	100
12-4	375	884	318	23	34	0.50	-	-	-	-	-	-	1.432	0.55	0.05	0.830	0.002	0.6	9.38	-	0	0
2-6-76	130	761	464	30	48	0.10	-	-	-	-	-	-	-	-	-	-	-	-	13.20*	-	-	-
3-4	409	1,085	625	18	23	0.26	5.30	2.80	1.70	2.40	5.65	2.30	1.711	0.86	0.04	0.800	0.011	0.6	11.50*	-	0	100
4-8	480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-6	441	733	391	145	236	0.20	-	-	-	-	-	-	1.353	0.73	0.07	0.548	0.005	1.8	9.22	-	0	100
6-3	868	700	391	155	296	0.22	3.65	1.55	1.35	1.98	3.23	1.75	2.202	1.61	0.09	0.500	0.002	0.6	10.80	8.0	0	0
7-8	644	707	406	115	208	0.35	-	-	-	-	-	-	2.738	1.10	0.10	1.480	0.038	0.6	8.50	7.9	0	0
8-5	609	767	453	110	216	0.15	-	-	-	-	-	-	2.252	1.27	0.03	0.940	0.012	2.4	8.80	7.9	0	100
9-9	511	736	433	75	134	0.22	3.50	1.90	1.50	2.16	3.53	1.55	0.947	0.41	0.09	0.440	0.007	0.6	9.00	8.3	0	0
10-7	318	781	438	55	82	0.26	-	-	-	-	-	-	1.303	0.41	0.06	0.840	0.013	0.6	9.14	8.4	0	0
11-4	329	1,067	597	36	43	0.50	-	-	-	-	-	-	1.300	0.95	0.05	0.290	0.005	0.6	8.66	8.6	0	0
12-16	-	1,020	615	23	33	0.20	-	-	-	-	-	-	1.020	0.58	0.12	0.320	0	4.2	10.63	8.1	0	0
1-6-77	-	1,367	785	24	20	0.55	7.75	3.25	2.25	2.17	5.87	4.60	1.080	0.95	0.10	0.030	0.001	1.2	11.00	8.4	0	0

Date	Monthly flow (ac-ft)	EC (µmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml Total	Fecal
							meq/l						mg/l									
LBNA-8 West Delta Canal																						
11-6-75	536	426	249	34	67	0.10	-	-	-	-	-	-	1.263	0.71	0.09	0.456	0.007	1.2	9.67	-	0	0
12-4	76	780	454	27	44	0.30	-	-	-	-	-	-	1.556	0	2.10	0.850	0.004	0.6	9.38	-	0	0
2-6-76	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-6	96	1,016	582	17	21	0.26	5.30	2.50	1.60	2.92	4.18	2.60	2.566	0.94	0.06	1.500	0.064	1.2	11.50*	-	0	100
4-8	436	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-6	729	1,316	635	52	117	0.25	-	-	-	-	-	-	1.360	1.23	0.07	0.244	0.016	4.8	9.80	-	0	0
6-3	205	933	522	62	135	0.30	6.80	2.00	1.65	2.40	4.50	2.60	1.967	1.65	0.05	0.460	0.007	1.2	11.20	8.1	0	0
7-8	113	1,219	706	46	93	0.86	-	-	-	-	-	-	3.323	1.36	0.16	1.700	0.123	4.2	8.60	7.9	0	200
8-5	237	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-9	475	1,205	719	44	85	0.32	5.88	2.80	2.30	2.92	6.18	1.60	1.472	0.44	0.26	0.710	0.062	1.8	9.00	8.2	0	100
10-7	168	763	416	17	132	0.16	-	-	-	-	-	-	1.300	0.35	0.10	0.840	0.015	4.2	9.14	8.3	0	0
11-4	411	1,233	709	32	50	0.40	-	-	-	-	-	-	1.440	0.59	0.11	0.720	0.017	0.6	8.67	7.6	200	0
12-16	281	2,448	1,486	23	39	0.50	-	-	-	-	-	-	1.000	0.46	0.36	0.190	0.007	0.6	10.63	7.9	0	100
1-6-77	-	1,939	1,207	14	14	1.23	10.50	4.75	4.00	2.30	6.44	10.00	3.650	0.91	0.09	2.400	0.050	1.2	10.17	8.1	0	0
3-3	-	2,125	1,207	5	20	0.35	-	-	-	-	-	-	6.090	0.44	0.50	4.750	0.260	1.2	8.67	8.6	0	0
LBNA-9 Buttonwillow Lake Outflow																						
12-6-75	-	1,337	769	7	7	0.52	-	-	-	-	-	-	2.682	1.77	0.53	0.152	0.030	5.4	9.71	-	0	[illegible]
2-6-76	-	1,186	713	14	16	0.32	-	-	-	-	-	-	-	-	-	-	-	-	14.00*	-	-	-
3-6	-	1,301	753	26	35	0.45	7.00	2.75	2.50	3.97	6.06	2.15	2.566	2.30	0.20	0.060	0.004	4.2	10.80*	-	0	0
4-8	-	1,453	811	53	89	0.52	-	-	-	-	-	-	-	-	-	-	-	-	9.90*	-	-	-
5-6	-	1,558	880	39	60	0.42	-	-	-	-	-	-	2.415	2.36	0.06	0.043	0.002	7.2	9.30	-	0	100
6-3	-	1,803	1,051	21	20	0.52	11.25	3.75	3.30	6.59	9.97	3.90	3.007	2.98	0.02	0.007	0.000	5.4	11.20	8.3	0	100
7-7	-	1,876	1,086	63	38	0.52	-	-	-	-	-	-	2.466	2.36	0.00	0.008	0.008	2.4	9.00	8.4	0	0
8-4	-	1,688	958	22	36	0.55	-	-	-	-	-	-	1.440	[illegible]	0.05	0.022	0.070	3.6	8.89	8.7	0	100
12-16	-	1,461	866	14	680	0.10	-	-	-	-	-	-	1.730	1.33	0.22	0.170	0.012	1.2	9.71	8.1	0	0
1-6-77	-	1,499	828	10	22	0.32	8.50	3.00	3.25	4.38	7.11	3.35	1.860	1.28	0.32	0.250	0.013	1.8	10.33	8.3	0	0
2-3	-	1,612	925	5	5	0.35	-	-	-	-	-	-	1.580	0.75	0.25	0.560	0.021	1.2	8.89	8.3	0	0
3-3	-	1,700	1,029	26	53	0.35	-	-	-	-	-	-	2.200	1.76	0.46	0.002	0.002	0.6	9.00	8.7	0	0

Date	Monthly Flow (ac-ft)	EC (µmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NO_3-N	NH_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml Total	Fecal
							meq/l						mg/l									
LBM-10 Mud Slough Outlet																						
11-8-75	-	1,710	991	47	103	0.80	-	-	-	-	-	-	1.440	1.12	0.18	0.140	0.098	0.6	9.67	-	300	300
12-6	-	2,080	1,238	38	21	1.40	-	-	-	-	-	-	1.582	1.16	0.19	0.216	0.016	6.2	9.71	-	0	100
1-8-76	-	3,677	2,311	27	30	2.80	-	-	-	-	-	-	1.307	1.06	0.24	0.062	0.085	1.8	8.67	-	100	0
2-6	-	2,372	1,841	27	40	2.06	-	-	-	-	-	-	-	-	-	-	-	-	13.20*	-	-	-
3-6	1,510	2,082	1,283	26	31	1.23	10.83	5.00	6.30	3.65	10.32	6.65	2.060	1.42	0.28	0.200	0.080	0.6	11.20*	-	0	0
4-8	2,250	2,048	1,215	65	80	1.20	-	-	-	-	-	-	-	-	-	-	-	-	10.16*	-	-	-
5-6	1,170	1,286	708	58	130	0.32	-	-	-	-	-	-	1.776	1.30	0.11	0.256	0.018	6.0	9.40	-	0	0
6-3	2,360	1,290	717	82	280	0.40	6.70	2.90	2.50	2.30	6.70	3.70	2.150	1.72	0.08	0.340	0.030	9.0	11.20	8.1	0	100
7-8	1,880	1,259	686	88	233	0.43	-	-	-	-	-	-	4.140	2.00	0.32	1.700	0.100	0.6	8.70	7.7	0	100
8-5	2,361	1,205	780	93	235	0.35	-	-	-	-	-	-	4.731	2.90	0.72	0.040	0.111	1.8	8.90	7.9	0	100
9-9	1,340	1,332	788	35	67	0.32	6.70	3.00	2.30	3.13	7.16	2.15	1.530	0.30	0.80	0.400	0.078	0.6	8.75	8.0	200	100
10-7	1,271	1,562	868	27	61	0.63	-	-	-	-	-	-	1.386	0.63	0.27	0.440	0.036	1.2	9.16	8.1	800	300
11-4	1,233	1,682	976	47	90	0.83	-	-	-	-	-	-	2.230	1.37	0.33	0.530	0.023	4.8	8.66	7.8	0	100
12-10	389	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-6-77	1,170	2,086	1,303	30	41	1.40	17.25	6.00	5.25	5.01	13.31	10.25	1.600	1.08	0.32	0.190	0.008	3.0	8.67	8.3	0	0
2-3	1,086	3,226	2,136	22	33	3.28	-	-	-	-	-	-	2.070	1.07	0.43	1.410	0.033	0.6	8.67	8.0	0	100
3-3	1,463	3,710	2,717	37	116	3.90	-	-	-	-	-	-	11.280	1.80	0.80	8.420	0.180	2.6	8.75	8.3	0	0
LBM-12 Ro h Lobo Low Lift Pump																						
11-8-75	-	1,580	910	18	28	0.90	-	-	-	-	-	-	1.408	1.12	0.08	0.087	0.001	2.6	9.67	-	200	0
12-6	-	1,790	1,025	16	10	1.00	-	-	-	-	-	-	1.206	1.17	0.03	0.006	0.000	6.2	9.60	-	0	0
1-8-76	-	2,820	1,816	13	41	2.00	-	-	-	-	-	-	1.308	1.28	0.02	0.000	0.080	6.2	8.82	-	100	0
2-6	-	2,080	1,308	16	13	1.62	-	-	-	-	-	-	-	-	-	-	-	-	12.60*	-	-	-
3-6	-	2,440	1,376	25	26	1.48	16.25	5.75	6.30	5.01	11.30	0.13	2.874	1.89	0.11	0.005	0.030	0.6	11.10*	-	0	0
4-8	-	2,438	1,631	30	62	1.86	-	-	-	-	-	-	-	-	-	-	-	-	10.66*	-	-	-
5-6	-	2,384	1,721	43	77	1.98	-	-	-	-	-	-	4.032	3.91	0.08	0.010	0.002	9.1	9.70	-	0	0
6-3	-	2,217	1,360	36	63	1.25	16.30	3.50	6.00	3.36	11.06	7.09	40.220	3.90	0.10	0.012	0.001	13.2	11.20	8.4	200	0
7-8	-	1,525	871	44	73	0.28	-	-	-	-	-	-	2.007	2.75	0.05	0.100	0.007	9.6	8.60	8.5	0	0
8-5	-	1,337	816	38	66	0.33	-	-	-	-	-	-	3.306	3.26	0.06	0.044	0.002	13.8	8.80	8.9	0	0
9-9	-	1,444	883	60	112	0.80	8.00	3.40	3.00	3.26	7.00	3.75	2.640	0.77	0.73	0.100	0.620	3.0	8.75	8.2	0	100
10-7	-	1,448	779	22	36	0.30	-	-	-	-	-	-	1.353	1.00	0.12	0.140	0.013	4.8	9.16	8.5	0	0
11-4	-	1,730	1,022	26	50	0.90	-	-	-	-	-	-	1.520	1.27	0.10	0.060	0.010	1.8	9.25	8.8	0	0
12-10	-	1,856	1,110	23	25	0.70	-	-	-	-	-	-	2.680	1.80	0.80	0	0	2.8	9.85	8.6	0	0
1-6-77	-	1,908	1,111	47	22	0.95	11.25	6.00	6.30	4.30	8.03	5.80	3.540	3.67	0.03	0.038	0	12.6	9.90	8.6	0	0
2-3	-	2,366	1,453	38	36	1.40	-	-	-	-	-	-	3.080	2.86	0.22	0.003	0	8.0	8.76	8.6	0	0
3-3	-	2,310	1,840	30	38	1.63	-	-	-	-	-	-	2.836	2.70	0.10	0.062	0	3.6	8.89	8.7	0	0

Date	Monthly flow (ac-ft)	EC (µmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	DO	pH	coliform/100 ml Total	Fecal
							meq/l						mg/l									
LBWA-13 Rush Lake Discharge																						
11-6-75	-	2,980	1,994	24	45	2.15	-	-	-	-	-	-	1.905	1.86	0.04	0.003	0.002	2.4	8.75	-	200	100
12-4	-	1,863	1,128	8	7	1.50	-	-	-	-	-	-	1.260	1.16	0.09	0.008	0.002	3.6	9.86	-	0	0
2-6-76	-	2,372	1,626	12	8	1.90	-	-	-	-	-	-	-	-	-	-	-	-	13.20*	-	-	-
3-4	-	3,091	2,082	12	11	2.65	18.00	7.75	7.25	5.95	13.42	15.00	1.660	1.55	0.03	0.010	0.050	0.6	11.60*	-	0	0
4-8	-	3,472	2,282	11	17	3.00	-	-	-	-	-	-	-	-	-	-	-	-	10.84*	-	-	-
7-8	-	2,079	1,246	18	22	1.35	-	-	-	-	-	-	2.879	2.78	0.02	0.072	0.007	6.6	8.70	7.9	0	0
8-5	-	1,932	1,160	50	62	1.06	-	-	-	-	-	-	6.372	6.18	0.02	0.168	0.004	2.1	9.00	6.9	0	0
9-9	-	2,181	1,165	69	98	1.00	13.75	2.80	2.90	1.77	11.87	6.60	8.916	8.57	0.23	0.110	0.006	30.0	9.28	7.8	0	100
10-7	-	1,603	925	19	8	0.95	-	-	-	-	-	-	3.284	3.13	0.07	0.080	0.006	3.0	8.68	8.5	0	0
11-4	-	2,238	1,397	11	11	1.42	-	-	-	-	-	-	2.630	1.72	0.88	0.020	0.010	4.8	8.77	8.8	400	200
12-16	-	1,998	1,325	27	15	0.32	-	-	-	-	-	-	3.060	2.13	0.67	0.250	0.007	10.2	9.83	8.2	100	0
1-6-77	-	2,897	1,815	11	3	2.10	16.75	7.00	6.25	5.64	11.96	13.00	1.630	1.43	0.17	0.030	0.004	4.2	8.75	7.8	0	0
2-3	-	3,224	1,964	4	63	2.75	-	-	-	-	-	-	1.240	0.93	0.27	0.038	0.002	0.6	8.89	8.6	0	0
3-3	-	3,290	2,292	3	6	2.73	-	-	-	-	-	-	1.150	0.88	0.22	0.052	0.002	2.4	8.89	8.2	0	0
LBWA-14 Field 37 and 38 Discharge																						
12-4-75	-	2,267	1,331	5	17	1.50	-	-	-	-	-	-	1.643	1.48	0.12	0.038	0.005	3.0	9.38	-	200	0
3-4-76	-	2,914	1,809	27	34	1.02	18.75	5.75	5.75	5.95	17.36	8.25	2.320	2.21	0.09	0.020	0.000	2.4	11.40*	-	200	100
4-8	-	2,719	1,574	30	40	1.10	-	-	-	-	-	-	-	-	-	-	-	-	9.87*	-	-	-
5-6	-	2,092	1,182	30	1,182	0.70	-	-	-	-	-	-	2.721	2.65	0.05	0.019	0.002	6.6	9.33	-	0	300
6-3	-	2,046	1,200	32	1,063	0.65	11.25	2.75	7.75	4.59	11.66	4.51	3.205	3.07	0.13	0.005	0.000	12.6	11.20	8.1	0	0
7-8	-	2,194	1,259	43	66	0.90	-	-	-	-	-	-	5.007	4.84	0.06	0.100	0.007	12.0	8.70	7.9	100	0
9-9	-	2,765	1,657	39	92	1.04	19.25	4.00	4.50	4.49	17.62	7.00	5.319	4.60	0.60	0.110	0.009	9.0	8.98	8.2	0	0
10-7	-	2,648	1,480	10	8	0.95	-	-	-	-	-	-	3.999	2.91	0.99	0.092	0.007	0.6	8.57	8.5	400	100
11-4	-	2,582	1,568	6	3	2.17	-	-	-	-	-	-	1.470	1.04	0.41	0.018	0.004	3.0	8.56	8.2	0	0
12-16	-	1,761	1,037	17	8	1.44	-	-	-	-	-	-	2.420	1.20	1.00	0.140	0.078	0.6	10.08	8.0	0	0
1-6-77	-	2,308	1,250	10	6	0.65	14.50	4.00	5.12	5.43	12.18	5.60	2.150	1.50	0.25	0.380	0.021	1.8	10.37	8.3	0	0
2-3	-	2,217	1,282	7	25	0.60	-	-	-	-	-	-	2.000	1.69	0.31	0.003	0	3.6	8.62	8.3	0	0
3-3	-	2,550	1,493	3	13	0.72	-	-	-	-	-	-	1.170	0.82	0.28	0.062	0.008	6.0	8.89	8.2	100	0

*Field measurements

LBWA-3 flow is estimated

Appendix Table 32:

Irrigated Crop and Refuge Acreage for Glenn-Colusa Irrigation District, in 1975-1976

Crop	Acres (1975)	Acres (1976)
Rice	93,326	81,190
Tomatoes	1,005	1,032
Sugar Beets	1,633	1,572
Clover	5,646	5,182
Alfalfa	1,845	2,161
Corn	1,944	6,217
Orchard	1,797	1,874
General	6,293	15,466
Duck Pond	2,392	2,733
One Irrigation	8,281	11,460
Second Irrigation	2,124	4,513
Subtotal	126,286	133,400

Refuge	Acres (1975)	Acres (1976)
Rice	750	857
General	2,300	2,169
Duck Pond	3,100	3,273
Subtotal	6,150	6,299
GRAND TOTAL	132,436	140,234

Appendix Table 33:

Glenn-Colusa Irrigation District

Monthly Drain Outflows 1976

(acre-feet)

Location	April	May	June	July	Aug.	Sept.	Oct.	Total
D1 Salmon Hole	840	630	20	50	390	320	0	2,300
D2 Bondurant	1,430	30	0	0	0	320	320	2,100
D3 Drain 55	2,720	8,500	8,480	4,050	3,850	3,500	800	31,900
D4 Logan Creek	440	1,020	0	80	2,720	870	370	5,500
D5 2047 at Sidds Road	1,050	2,250	1,500	1,880	2,120	2,480	490	11,800
D6 Willow Creek	1,370	3,760	420	1,890	3,630	3,260	1,370	15,700
D7 Hunter Creek	870	2,200	170	700	2,890	2,790	780	10,400
D8 Stone Corral	1,950	4,830	1,990	2,500	4,370	7,120	2,140	24,900
D9 Kuhl Weir	2,300	1,600	470	810	2,240	4,350	1,330	13,100
D10 Section 25	1,610	2,260	1,150	230	3,280	2,940	1,230	12,700
D11 Freshwater Creek	1,900	2,840	1,120	2,890	3,800	2,780	1,270	16,600
Total Measured	16,480	29,920	15,320	15,080	29,320	30,780	10,100	147,000
Estimated District Total	20,600	37,400	19,100	18,900	36,700	38,500	12,600	183,800

Appendix Table 34:

Water Flow and Quality Data for Stations in
Colusa Basin Study Area
April 1976 Through October 1976

Date	Monthly flow (ac-ft)	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
GCID Main Canal, D-14 - Supply Water						
4-5	127,200	147	114	15	20	--
5-3	166,600	138	103	12	13	--
6-7	163,900	132	91	7	13	8.0
7-12	168,100	122	89	4	7	--
8-3	140,400	126	95	4	12	8.1
9-7	66,600	134	97	5	11	8.2
10-4	33,200	134	87	4	8	7.9
TOTAL	866,000					
GCID 2047 at Sidds Road, D-5 - (CBD-5)						
4-5	1,050	316	207	14	12	--
5-3	2,250	327	207	72	157	--
6-7	1,500	342	191	11	21	8.1
7-12	1,880	307	186	14	24	--
8-3	2,120	296	184	13	34	8.0
9-7	2,480	313	194	9	20	8.1
10-4	490	494	275	8	13	8.0
TOTAL	11,800					
GCID Bondurant, D-2						
4-5	1,430	209	144	23	36	--
5-3	30	288	181	17	28	--
6-7	0	357	200	12	24	8.2
7-12	0	344	216	7	15	--
8-3	0	351	224	10	26	7.9
9-7	320	383	240	5	13	8.1
10-4	320	435	260	7	13	7.9
TOTAL	2,100					

Appendix Table 34: Continued

Date	Monthly flow (ac-ft)	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
GCID Drain 55, D-3						
4-5	2,720	293	190	13	12	—
5-3	8,500	283	183	13	18	—
6-7	8,480	287	166	4	5	8.1
7-12	4,050	301	186	7	11	--
8-3	3,850	310	193	15	32	8.0
9-7	3,500	351	207	5	16	8.3
10-4	800	389	236	6	9	7.8
TOTAL	31,900					
GCID Willow Creek, D-6						
4-5	1,370	308	198	27	34	--
5-3	3,760	336	222	16	21	—
6-7	420	332	192	17	21	8.2
7-12	1,890	324	195	7	8	—
8-3	3,630	326	202	8	16	8.2
9-7	3,260	377	222	7	20	8.1
10-4	1,370	367	207	24	36	8.0
TOTAL	15,700					
GCID Salmon Hole, D-1						
4-5	840	237	159	32	39	—
5-3	630	373	243	14	18	--
6-7	20	464	273	3	5	8.2
7-12	50	471	299	4	4	—
8-3	390	362	221	5	12	8.2
9-7	320	406	252	3	5	8.2
10-4	0	466	290	16	16	8.0
TOTAL	2,300					

Appendix Table 34: Continued

Date	Monthly flow (ac-ft)	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
GCID Logan Creek, D-4						
4-5	440	1,242	786	46	85	--
5-3	1,020	498	315	38	65	--
6-7	0	668	391	31	41	8.1
7-12	80	534	327	18	20	—
8-3	2,720	543	348	24	40	8.2
9-7	870	548	342	25	51	7.9
10-4	320	621	379	32	59	7.9
TOTAL	5,500					
GCID Hunter Creek, D-7						
4-5	870	246	162	39	62	--
5-3	2,200	323	172	26	35	--
6-7	170	517	290	35	49	8.3
7-12	700	357	212	14	20	—
8-3	2,890	350	219	17	27	8.1
9-7	2,790	371	218	21	41	8.0
10-4	280	773	419	31	58	8.5
TOTAL	10,400					
GCID Stone Corral, D-8						
4-5	1,950	348	224	45	64	—
5-3	4,830	340	202	40	69	—
6-7	1,990	503	290	44	60	8.2
7-12	2,500	540	332	7	23	--
8-3	4,370	427	265	28	50	8.0
9-7	7,120	415	249	30	59	8.0
10-4	2,140	352	214	56	87	8.1
TOTAL	24,900					

Appendix Table 34: Continued

Date	Monthly flow (ac-ft)	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
GCID Kuhl Weir, D-9						
4-5	2,300	298	199	83	133	--
5-3	1,600	363	233	20	23	--
6-7	470	375	219	14	14	8.1
7-12	810	359	216	16	27	--
8-3	2,240	373	234	13	27	7.9
9-7	4,350	367	215	12	21	8.1
10-4	1,330	394	243	38	60	8.1
TOTAL	13,100					
GCID Section 25, D-10						
4-5	1,610	220	148	170	318	--
5-3	2,260	340	219	84	122	--
6-7	1,150	548	316	71	81	8.5
7-12	230	346	212	19	28	--
8-3	3,280	352	222	17	29	8.1
9-7	2,940	345	209	22	41	8.3
10-4	1,230	366	212	19	152	8.0
TOTAL	12,700					
GCID Freshwater Creek, D-11						
4-5	1,900	343	226	200	277	--
5-3	2,840	716	443	84	146	--
6-7	1,120	1,265	720	32	43	8.6
7-12	2,890	678	411	21	36	--
8-3	3,800	593	364	42	70	8.2
9-7	2,780	551	327	86	167	8.3
10-4	1,270	603	375	78	151	8.2
TOTAL	16,600					

Appendix Table 35:

Water Flow and Quality Data for Stations in Colusa Basin Study Area November 1975 Through March 1976

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Station: 2047 at Sidds Road (D-5)					
11-3	923	573	326	13	24
12-1	615	599	338	6	12
1-5	615	606	348	6	8
2-2	230	598	468	9	3
3-1	921	173	120	135	201
TOTAL	3,304				
Station: Bondurant (D-2)					
11-3	298	352	208	4	1
12-1	1,230	177	124	15	24
1-5	308	532	307	4	2
2-2	173	517	322	7	2
3-1	510	309	188	28	36
TOTAL	2,519				
Station: Drain 55 (D-3)					
11-3	595	522	301	5	3
12-1	1,230	506	327	7	15
1-5	431	532	313	9	14
2-2	288	512	299	10	13
3-1	927	195	133	55	89
TOTAL	3,471				
Station: Willow Creek (D-6)					
11-3	1,190	282	165	16	24
12-1	2,460	261	153	20	33
1-5	1,230	579	315	17	37
2-2	575	554	344	17	15
3-1	615	218	145	290	385
TOTAL	6,070				

Appendix Table 35: Continued

Date	Monthly flow (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Station: Salmon Hole (D-1)					
11-3	298	555	316	37	99
12-1	308	316	202	8	10
1-5	123	606	348	6	8
2-2	58	598	468	9	3
3-1	554	173	120	135	201
TOTAL	1,341				
Station: Logan Creek (D-4)					
11-3	893	527	322	23	40
12-1	1,538	606	389	15	24
1-5	1,538	1,064	643	17	20
2-2	1,150	985	653	46	74
3-1	367	1,183	749	39	56
TOTAL	5,486				
Station: Hunter Creek (D-7)					
11-3	298	492	281	21	37
12-1	923	386	228	31	51
1-5	923	1,272	693	12	29
2-2	288	2,128	1,372	67	143
3-1	515	542	328	58	89
TOTAL	2,947				
Station: Stone Corral (D-8)					
11-3	893	621	362	24	37
12-1	2,460	407	240	26	44
1-5	1,230	1,003	564	25	65
2-2	575	950	568	32	65
3-1	655	296	192	150	222
TOTAL	5,813				

Appendix Table 35: Continued

Date	Monthly flow (ac-ft)	EC (umhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Station: Kuhl Weir (D-9)					
11-3	595	573	329	28	43
12-1	308	869	487	8	16
1-5	308	1,172	673	20	58
2-2	173	1,132	684	12	20
3-1	732	277	78	78	122
TOTAL	2,116				
Station: Section 25 (D-10)					
11-3	1,190	424	249	22	28
12-1	615	511	293	13	14
1-5	492	1,033	576	12	14
2-2	173	1,043	627	15	8
3-1	375	279	178	58	78
TOTAL	2,845				
Station: Freshwater Creek (D-11)					
11-3	298	1,213	722	13	19
12-1	615	1,064	625	15	27
1-5	615	1,033	576	12	14
2-2	115	1,043	627	15	8
3-1	837	279	178	58	78
TOTAL	2,480				

Appendix Table 36:

Water Flow and Quality Data for Stations in
Colusa Basin Study Area
November 1976 Through March 1977

Date	Monthly flow (ac-ft)	EC x 10^6 (µmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	pH
GCID 2047 at Sidds Road, D-5						
11-1	246	316	198	16	18	7.7
12-6	123	590	277	4	12	8.0
1-3	614	279	168	335	285	7.7
2-7	166	600	295	23	45	8.1
3-7	923	306	191	12	24	7.8
TOTAL	2,072					
GCID Bondurant, D-2						
11-1	200	422	250	4	4	7.8
12-6	184	540	250	3	18	7.9
1-3	921	235	152	975	735	7.8
2-7	166	560	316	14	19	8.1
3-7	246	331	196	22	32	7.6
TOTAL	1,717					
GCID Drain 55, D-3						
11-1	325	370	219	6	8	7.9
12-6	184	521	279	7	15	8.1
1-3	1,535	236	152	2,900	1,630	7.5
2-7	222	543	287	10	19	8.2
3-7	923	272	172	49	119	7.4
TOTAL	3,189					
GCID Willow Creek, D-6						
11-1	323	415	238	14	13	8.2
12-6	268	331	198	8	8	8.0
1-3	614	476	179	256	124	8.2
2-7	222	586	317	22	33	8.2
3-7	615	245	159	31	52	7.7
TOTAL	2,042					

Appendix Table 36: Continued

Date	Monthly flow (ac-ft)	EC x 10^6 (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
GCID Salmon Hole, D-1						
11-1	59	291	165	9	12	7.8
12-6	123	595	358	8	9	8.2
1-3	61	567	324	22	21	8.6
2-7	55	671	386	28	41	8.3
3-7	123	490	287	12	25	7.9
TOTAL	421					
GCID Logan Creek, D-4						
11-1	303	541	337	14	13	8.2
12-6	491	617	366	18	23	7.8
1-3	921	1,005	619	46	41	8.1
2-7	2,218	895	554	46	65	7.8
3-7	923	979	604	36	65	7.8
TOTAL	4,856					
GCID Hunter Creek, D-7						
11-1	667	276	175	58	77	8.1
12-6	737	775	482	23	44	8.2
1-3	614	1,077	585	380	551	8.0
2-7	388	1,378	775	35	37	8.3
3-7	492	526	308	65	130	7.9
TOTAL	2,898					
GCID Stone Corral, D-8						
11-1	1,235	410	248	29	30	8.3
12-6	614	901	498	76	261	8.3
1-3	2,762	1,112	532	3,950	4,699	7.9
2-7	444	1,133	631	32	52	8.4
3-7	2,153	426	259	87	371	7.5
TOTAL	7,208					

Appendix Table 36: Continued

Date	Monthly flow (ac-ft)	EC x 10^6 (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH
GCID Kuhl Weir, D-9						
11-1	1,285	610	300	12	15	8.1
12-6	430	917	523	9	13	8.2
1-3	1,841	1,091	616	370	563	8.2
2-7	222	1,214	717	18	23	8.2
3-7	738	326	202	35	76	7.6
TOTAL	4,516					
GCID Section 13, D-10						
11-1	1,226	385	231	11	12	8.5
12-6	246	654	375	9	10	8.6
1-3	307	1,071	554	1,625	1,260	7.9
2-7	111	1,216	707	26	20	8.2
3-7	369	777	425	40	61	8.0
TOTAL	2,259					
GCID Freshwater Creek, D-11						
11-1	1,683	625	381	23	25	7.7
12-6	184	1,408	862	14	15	8.5
1-3	307	1,762	1,055	260	282	8.1
2-7	111	1,759	1,093	32	35	8.3
3-7	615	556	333	73	181	7.9
TOTAL	2,900					

Appendix Table 37:

Relation Between TDS and EC in the Glenn-Colusa

Irrigation District Monitoring Stations for the 1976 Irrigation Season

Station	Range of Values		Coefficients for $TDS = a_o + a_1 EC$		Correlation Coefficient r
	EC (µmhos/cm)	TDS (mg/ℓ)	a_o	a_1	
Supply Canal:					
D-14	122-147	87-114	-27.71	0.93	0.81
Lateral Drains:					
D-5	296-494	184-275	54.47	0.44	0.96
D-2	209-435	144-260	33.52	0.53	0.94
D-3	283-389	166-236	21.00	0.55	0.99
D-6	308-377	192-222	98.52	0.32	0.63
D-1	237-471	159-299	25.34	0.56	0.99
D-4	498-1,242	315-786	-11.44	0.64	0.99
D-7	246-773	162-419	31.85	0.50	0.99
D-8	340-540	202-332	14.55	0.57	0.98
D-9	298-394	199-243	74.35	0.41	0.64
D-10	220-548	148-316	37.17	0.51	0.71
D-11	343-1,265	226-720	44.69	0.54	1.00

Appendix Table 38:

Relation Between Turbidity and SS in the Monitoring Stations in Glenn-Colusa Irrigation District for the 1976 Irrigation Season

Station	Range of Values Turbidity (JTU)	SS (mg/ℓ)	Coefficients for $SS = a_o + a_1$ Turbidity a_o	a_1	Correlation Coefficient r
Supply Canal:					
D-14	4-15	7-20	6.02	0.82	0.86
Lateral Drains:					
D-5	8-72	12-157	-15.03	2.05	0.99
D-2	5-23	13-36	7.22	1.29	0.94
D-3	4-15	5-32	1.88	1.43	0.73
D-6	7-27	8-36	3.11	1.13	0.96
D-1	3-32	4-39	1.78	1.12	0.98
D-4	18-46	20-85	-12.02	2.08	0.94
D-7	14-39	20-62	1.50	1.54	0.92
D-8	7-56	23-87	16.78	1.18	0.95
D-9	12-83	14-133	-1.61	1.61	0.99
D-10	17-170	28-318	19.60	1.58	0.86
D-11	21-200	36-277	20.21	1.38	0.97

Appendix Table 39:

Detailed Water Quality Analysis for GCID Supply Water and Eleven Lateral Drains in Colusa Basin Study Area 1976-1977

Date	EC (µmhos/cm)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	pH
					meq/ℓ						ppm				
Supply Station for Glenn-Colusa Irrigation District															
GCID Main Canal, D-14															
6-7-76	132	0.29	0.46	0.50	0.03	1.15	0.09	0.08	1.145	1.06	0.04	0.044	0.001	1.2	8.0
9-7-76	134	0.36	0.44	0.42	0.04	1.20	0.11	0.08	0.516	0.36	0.04	0.152	0.004	0.6	8.2
1-3-77	149	0.36	0.48	0.58	0.04	1.15	0.13	0.08	1.469	1.09	0.11	0.268	0.001	6.6	7.9
Lateral Drains in Glenn-Colusa Irrigation District															
GCID 2047 at Sidds Road, D-5															
6-7-76	342	0.63	1.18	1.55	0.03	2.87	0.27	0.33	1.106	0.82	0.08	0.196	0.010	0.6	8.1
9-7-76	313	0.57	1.23	1.35	0.05	3.08	0.20	0.16	0.836	0.49	0.11	0.224	0.012	0.6	8.1
1-3-77	279	0.43	1.03	1.08	0.15	1.83	0.29	0.51	4.644	2.53	0.47	1.600	0.044	7.8	7.7
GCID Bondurant, D-2															
6-7-76	357	0.50	1.40	1.60	0.02	3.24	0.13	0.30	1.598	1.16	0.04	0.384	0.014	0.6	8.2
9-7-76	383	0.57	1.80	1.65	0.06	3.92	0.24	0.20	1.492	0.93	0.17	0.380	0.012	0.6	8.1
1-3-77	235	0.29	0.95	0.88	0.09	1.62	0.18	0.40	4.779	3.14	0.26	1.350	0.029	9.0	7.8
Lateral Drains in Glenn-Colusa Irrigation District															
GCID Drain 55, D-3															
6-7-76	287	0.45	1.05	1.48	0.02	2.45	0.10	0.28	1.957	1.36	0.24	0.336	0.021	4.8	8.1
9-7-76	351	0.49	1.45	1.65	0.04	3.50	0.18	0.16	0.762	0.54	0.06	0.152	0.010	4.2	8.3
1-3-77	236	0.41	0.73	0.93	0.10	1.46	0.21	0.42	4.187	3.64	0.36	0.150	0.037	2.4	7.5
GCID Willow Creek, D-6															
6-7-76	332	0.70	1.05	1.55	0.02	2.98	0.00	0.32	2.669	2.24	0.06	0.352	0.017	0.6	8.2
9-7-76	377	0.90	1.40	1.55	0.05	3.71	0.21	0.24	1.147	0.73	0.07	0.330	0.017	3.6	8.1
1-3-77	476	1.13	1.70	2.15	0.07	3.86	0.13	0.85	2.825	1.40	0.20	1.200	0.025	8.4	8.2
GCID Salmon Hole, D-1															
6-7-76	464	1.22	1.30	2.40	0.01	4.12	0.07	0.60	0.908	0.85	0.05	0.008	0.000	12.6	8.2
9-7-76	406	1.22	1.40	1.65	0.07	4.02	0.29	0.36	1.203	0.91	0.19	0.096	0.007	1.8	8.2
1-3-77	567	1.90	1.70	2.80	0.04	5.06	0.21	0.83	0.790	0.61	0.14	0.040	0.000	4.8	8.6
GCID Logan Creek, D-4															
6-7-76	668	3.60	1.15	2.05	0.05	4.18	0.38	2.25	1.013	0.85	0.15	0.012	0.001	2.4	8.1
9-7-76	548	2.80	1.20	1.65	0.08	4.28	0.41	1.30	1.477	1.22	0.18	0.070	0.007	1.2	7.9
1-3-77	1005	6.20	1.40	3.10	0.10	4.28	0.80	5.20	1.630	1.06	0.24	0.216	0.114	2.4	8.1

Appendix Table 39: (continued)

Date	EC (µmhos/cm)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD	pH
					meq/ℓ						ppm				
GCID Hunter Creek, D-7															
6-7-76	517	2.25	1.15	1.25	0.05	2.35	1.25	1.30	1.538	0.20	1.20	0.128	0.010	1.8	8.3
9-7-76	371	1.65	1.10	0.90	0.05	2.87	0.55	0.41	0.729	0.55	0.05	0.120	0.009	1.8	8.0
1-3-77	1077	1.13	1.70	2.15	0.07	3.86	0.13	0.85	3.975	2.40	0.15	1.420	0.025	7.8	8.0
GCID Stone Corral, D-8															
6-7-76	503	2.65	0.90	1.05	0.04	2.82	0.92	1.15	1.417	1.17	0.13	0.104	0.013	0.6	8.2
9-7-76	415	2.00	0.75	1.00	0.05	3.18	0.63	0.53	1.098	0.83	0.07	0.188	0.010	1.2	8.0
1-3-77	1112	6.70	1.80	2.10	0.18	3.86	3.56	3.15	15.282	14.53	0.47	0.220	0.062	1.2	7.9
GCID Kuhl Weir, D-9															
6-7-76	375	1.85	0.78	1.03	0.02	2.45	0.30	0.76	1.544	1.45	0.05	0.040	0.004	1.8	8.1
9-7-76	367	1.55	1.20	1.00	0.06	3.03	0.35	0.52	0.901	0.72	0.08	0.092	0.009	2.4	8.1
1-3-77	1091	6.30	1.80	2.50	0.13	4.49	2.44	3.50	5.796	3.16	1.14	1.460	0.036	6.6	8.2
GCID Section 25, D-10															
6-7-76	548	3.05	0.90	1.45	0.02	2.77	0.97	1.52	2.028	1.85	0.05	0.120	0.008	1.2	8.5
9-7-76	345	1.55	0.95	1.00	0.04	2.77	0.44	0.42	0.919	0.74	0.06	0.112	0.007	3.6	8.3
1-3-77	1071	7.40	1.50	2.00	0.24	3.65	2.66	4.30	7.016	5.36	0.14	1.400	0.116	4.8	7.9
GCID Freshwater Creek, D-11															
6-7-76	1265	7.70	1.80	2.50	0.05	3.65	3.14	5.60	1.854	1.60	0.10	0.148	0.006	0.6	8.6
9-7-76	551	2.95	1.20	1.25	0.05	3.45	0.89	1.30	0.929	0.72	0.08	0.120	0.009	0.6	8.3
1-3-77	1762	11.80	2.70	2.90	0.20	3.86	5.14	8.32	4.563	2.93	0.32	1.250	0.063	1.2	8.1

Appendix Table 40:

Glenn-Colusa Irrigation District

Sampling Locations - 1976 Irrigation Season

Rice Test Fields

4-1 Inlet for Rice Test Field #4

4-2 Outlet for Rice Test Field #4

4-3 Drain adjacent to Rice Test Field #4 and below discharge for Rice Test Field #4

4-4 Drain adjacent to and 250 yards above discharge point for Rice Test Field #4

4-5 Drain adjacent to and 200 yards above discharge point for Rice Test Field #4

8-1 Inlet for Field #8

8-2 Outlet for Field #8

8-3 N.E. inlet for Rice Check #18 in Field #8

8-4 N.W. inlet for Rice Check #18 in Field #8

8-5 S.E. inlet for Rice Check #18 in Field #8

8-11-1
8-11-2
8-11-3
8-11-4
8-11-5
8-11-6
8-11-7
Water probes for Field #8 in Rice Check #11

16-6 -1
16-6 -2
16-6 -3
16-6 -4
16-6 -5
16-6 -6
Water probes for Field #16 in Rice Check #6

8-18-1
8-18-2
8-18-3
8-18-4
8-18-5
8-18-6
Water probes for Field #8 in Rice Check #18

16-14-1
16-14-2
16-14-3
16-14-4
16-14-5
16-14-6
Water probes for Field #16 in Rice Check #14

13-1 Inlet for Rice Field #13

13-2 Outlet for Rice Field #13

16-1 Inlet for Rice Field #16

16-2 Outlet for Rice Field #16

16-3 N.W. inlet for Rice Check #14 in Field #16

16-4 S.W. inlet for Rice Check #14 in Field #16

Appendix Table 41:

Rice Test Fields - General Information

Glenn-Colusa Irrigation District

1976 Season

Characteristic	Field Number 4	8	13	16
SITE:				
Acres	138.7	141.3	50.3	74.9
SURFACE WATER SAMPLING:				
Inflow	yes	yes	yes	yes
Middle	no	yes	no	yes
Outflow	yes	yes	yes	yes
FERTILIZER:				
Form (rate-lbs/acre)	18(N)-46(P)-(100)	Urea-(500)	18(N)-46(P)-(150)	18(N)-46(P)-(100)
Form (rate-lbs/acre)	N-aqua-(90)		NH_3-(320)	Urea-(250)
When applied	4/18	4/17 to 4/19	4/20	4/26
How applied	18-46:airplane N-aqua:aqua-rig	ground rakes	airplane	airplane
Incorporate	no	yes	no	yes
TOP DRESSING:				
Part of program	yes	yes	no	yes
When applied	6/30	6/4		6/7
Fertilizer applied	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$		$(NH_4)_2SO_4$
Rate - lbs/acre	(150)	(200)		(145)
FLOODING:				
Start - finish	4/13 to 4/22	4/22 to 5/4 (two stages)	4/15 to 4/20	5/1 to 5/6
Inflow device	Hersey-Sparling meter	Hersey-Sparling meter	Hersey-Sparling meter	Hersey-Sparling meter
Outflow device	V-notch weir	V-notch weir	V-notch weir	V-notch weir
Days flooded*	145	123	134	133

* From date finished flooding to date all boards removed.

Appendix Table 41: Continued

Characteristic	Field Number			
	4	8	13	16
RICE:				
Variety	Serra Mia	CSM5	"Early Rose 76"	CSM5
lbs/acre	150	170	170	145
Planting date	4/23	5/1 to 5/5 (two stages)	4/27	5/7
HERBICIDE:				
When applied	5/5	no herbicide used	6/15	5/17
Type	ORDRAM		MCPA	ORDRAM
Rate - gls/acre	.30		.10	.35
When applied	6/17			
Type	MCPA			
Rate - gls/acre	.12			
PESTICIDE:				
When applied	4/11	4/20		
Type	BUX (for water weevil and shrimp)	BUX		
Rate - lbs/acre	10	10		
HARVEST:				
Stop inflow water	9/11	8/30	8/26	9/8
Drain field	9/15	9/6	9/2	9/14
Harvest rice	10/4	10/10	10/21	10/14
Yield - (cwt/acre green)	54 (dry)	58	79	54
COMMENTS:	-colder water in Field 4	-higher water was used to control water grass in place of ORDRAM -the CSM5 variety did not establish well initially	-high yield with a new field -"Early Rose 76" performed well	-the water level fluctuated often in Field 16 during the season -the CSM5 variety did not establish well; the third and fourth checks were reseeded

Appendix Table 42:

Rice Test Plot #4, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1976 Irrigation Season

Date	Inflow						Outflow					
	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)
5-11	5.18	130	100	13	11	0.03	0.14	138	114	42	43	0.19
5-17	8.56	128	93	12	10	0.10	0.02	144	104	15	9	0.10
5-26	8.96	127	94	12	10	0.02	0.25	119	86	10	6	0.09
6-7	9.78	119	90	7	19	0.08	0.89	110	69	5	9	0.02
6-21	8.99	119	85	6	12	0.09	0.51	100	86	2	6	0.00
7-12	10.46	118	81	6	7	0.05	0.33	94	72	3	5	0.00
7-26	10.77	124	101	11	28	0.07	0.69	107	90	2	2	0.06
8-9	10.71	128	98	5	6	0.13	0.89	125	96	14	11	0.10
8-23	8.75	129	87	9	14	0.12	2.22	127	85	16	22	0.10

Appendix Table 43:

Rice Test Plot #8, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1976 Irrigation Season

Date	Inflow						Outflow					
	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)
5-11	6.49	135	100	13	100	0.06	1.55	267	198	25	34	0.25
5-17	5.95	127	89	13	89	0.02	1.18	246	180	14	13	0.22
5-26	3.76	128	95	12	95	0.04	3.33	168	116	20	11	0.14
6-7	6.34	121	87	8	87	0.05	0.79	334	201	4	6	0.07
6-21	7.76	121	90	5	90	0.08	0.38	261	182	2	3	0.27
7-12	6.35	119	75	8	75	0.04	1.74	108	92	2	4	0.01
7-26	8.20	122	98	6	92	0.10	2.11	136	98	2	2	0.0
8-9	6.25	129	89	34	90	0.10	2.44	153	89	1	3	0.03
8-23	3.55	128	99	16	87	0.12	1.52	171	99	4	1	0.10

Appendix Table 44:

Rice Test Plot #13, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1976 Irrigation Season

Date	Inflow						Outflow					
	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)
5-11	4.36	133	98	13	10	0.05	2.58	155	110	26	29	0.08
5-17	2.52	159	110	14	7	0.04	0.05	128	87	12	8	0.13
5-26	3.97	128	91	11	5	0.02	0.00	122	99	12	16	0.14
6-7	2.60	121	88	7	14	0.05	0.19	108	90	1	4	0.00
6-21	3.35	123	85	5	19	0.10	0.14	91	83	2	1	0.00
7-12	3.33	123	84	8	7	0.04	0.21	126	92	2	1	0.00
7-26	2.63	158	97	7	9	0.12	0.25	122	109	2	2	0.30
8-9	1.33	129	98	5	10	0.11	0.67	159	100	0	1	0.03
8-23	1.36	130	90	9	11	0.12	0.34	161	96	3	10	0.10

Appendix Table 45:

Rice Test Plot #16, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1976 Irrigation Season

Date	Inflow						Outflow					
	Amount of water (ac-ft/day)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)	Amount of water (ac-ft/day)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Cl (meq/ℓ)
5-11	6.12	373	240	32	23	0.43	2.65	504	317	32	30	0.77
5-17	2.73	370	252	3	5	0.44	0.06	638	377	4	6	1.02
5-26	4.29	371	261	32	24	0.47	1.04	854	535	24	24	1.52
6-7	5.43	348	222	27	27	0.40	3.57	593	338	29	23	0.63
6-21	8.69	370	237	27	26	0.35	2.36	417	269	2	25	0.24
7-12	8.41	336	205	9	8	0.30	4.16	421	261	2	1	0.23
7-26	1.93	348	221	7	7	0.36	2.06	448	286	2	0	0.37
8-9	0.52	345	214	37	60	0.37	2.91	427	261	0	1	0.45
8-23	0.00	344	201	32	42	0.41	2.44	424	241	1	2	0.55

Appendix Table 46:

Water Quality Data for Stations Along Colusa Basin Drain in Colusa Basin Study Area - April 1976 Through October 1976

Date	EC (umhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	pH	Monthly flow (ac-ft)
Stations on Colusa Basin Drain:						
GCID 2047 at Sidde Road, D-5, is on the main drain, but also serves as a lateral for the district.						
CBD-4 at Princeton Road, D-15 †						
4-5	300	196	30	49	—	2,970
5-3	389	242	20	41	—	1,860
6-7	397	232	14	23	8.3	6,540
7-12	406	248	9	16	—	7,378
8-3	395	244	16	39	8.0	4,929
9-7	413	252	13	29	8.2	2,970
10-4	326	196	15	18	8.1	1,860
CBD-3 at Colusa Bridge, D-12						
4-5	352	225	82	159	—	18,589
5-3	606	359	53	100	—	41,780
6-7	849	496	28	45	8.4	14,221
7-12	654	407	19	31	—	26,699
8-3	579	363	25	52	8.2	56,916
9-7	535	319	51	130	8.2	53,814
10-4	632	402	53	96	7.9	10,370
CBD-2 at Davis Weir, D-13 †						
4-5	303	197	52	87	—	23,808
5-3	804	496	19	40	—	4,920
6-7	919	542	42	37	8.4	13,392
7-12	736	451	18	26	—	24,620
8-3	638	388	21	42	8.4	30,137
9-7	548	329	45	89	8.3	39,520
10-4	487	295	51	78	8.1	67,654
CBD-1 at Road 99E and Road 108						
4-5	382	234	81	115	—	13,080
5-3	336	215	41	58	—	29,363
6-7	945	540	44	40	8.5	1,921
7-12	799	504	68	85	—	6,970
8-3	695	424	32	46	—	34,890
9-7	569	341	55	94	8.2	37,870
10-4	558	349	56	75	8.2	7,531

† Represents estimated flow

Appendix Table 47:

Water Quality Data for Stations Along Colusa Basin Drain in Colusa Basin Study Area - November 1975 Through March 1976

Date	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Monthly flow (ac-ft)
Stations on Colusa Basin Drain:					
GCID 2047 at Sidds Road, D-5, is on the main drain, but also serves as a lateral for the district.					
CBD-4 at Princeton Road, D-15 †					
11-3	290	167	15	19	2,370
12-1	362	212	45	62	1,240
1-5	593	349	16	20	1,550
2-2	422	266	21	24	870
3-1	301	199	58	87	2,449
CBD-3 at Colusa Bridge, D-12					
11-3	705	416	20	33	14,797
12-1	621	365	34	53	9,858
1-5	1,086	667	23	26	11,403
2-2	771	485	57	66	10,203
3-1	419	262	130	193	22,840
CBD-2 at Davis Weir, D-13 †					
11-3	450	271	25	37	5,952
12-1	652	401	31	60	10,456
1-5	1,134	697	25	40	7,688
2-2	887	536	57	73	8,630
3-1	384	244	77	112	12,301
CBD-1 at Road 99E and Road 108					
11-3	884	515	56	70	18,040
12-1	745	455	34	48	17,800
1-5	1,064	650	14	15	5,890
2-2	1,064	657	47	55	2,620
3-1	470	292	72	99	16,510

†Represents estimated flow

Appendix Table 48:

Water Quality Data for Stations Along Colusa Basin Drain in Colusa Basin Study Area - November 1976 Through March 1977

Date	EC (umhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	pH	Monthly flow (ac-ft)
Stations on Colusa Basin Drain:						
GCID 2047 at Sidds Road, D-5, is on the main drain, but also serves as a lateral for the district.						
CBD-4 at Princeton Road, D-15†						
11-1	478	288	11	19	8.1	900
12-6	453	271	37	35	8.0	620
1-3	501	296	1,200	996	8.0	930
2-7	554	314	18	20	8.2	448
3-7	297	186	34	55	7.7	1,240
CBD-3 at Colusa Bridge, D-12						
11-1	662	415	44	62	7.9	15,170
12-6	862	517	29	32	8.1	8,479
1-3	1,129	617	365	363	8.1	19,170
2-7	1,214	749	49	57	8.1	10,060
3-7	597	365	66	134	7.8	15,770
CBD-2 at Davis Weir, D-13†						
11-1	413	241	24	38	8.2	6,547
12-6	840	580	38	52	8.0	3,690
1-3	1,257	712	430	357	8.1	15,376
2-7	1,244	760	40	45	8.0	2,778
3-7	462	285	63	116	7.7	7,380
CBD-1 at Road 99E and Road 108						
11-1	704	434	26	27	7.2	8,898
12-6	794	493	27	25	8.1	1;244
1-3	1,049	621	44	43	8.3	17,760
2-7	1,085	647	32	32	7.9	8,967
3-7	859	515	35	45	7.9	7,200

†Represents estimated flow.

Appendix Table 49:

Water Quality Analysis for Station CBD-1

in Colusa Basin Study Area

April 1976 Through October 1976

Date	EC (umhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH	Monthly flow (ac-ft)
4-5	382	234	81	115	—	2,970
4-13	330	224	82	120	—	
4-20	437	272	54	65	—	
4-27	474	308	80	96	—	
5-3	336	215	41	58	—	1,860
5-10	641	380	37	52	—	
5-17	638	394	43	69	—	
5-24	699	421	29	41	—	
6-1	962	582	28	37	—	6,540
6-7	945	540	44	40	8.5	
6-14	822	494	42	66	—	
6-21	763	462	44	72	—	
6-28	463	292	28	37	—	
6-30	194	124	91	131	—	
7-6	834	499	17	14	—	7,378
7-12	799	504	68	83	—	
7-19	811	502	64	86	—	
8-3	695	424	32	46	—	4,929
8-9	617	378	23	33	8.0	
8-16	573	348	28	50	7.9	
8-23	576	341	32	46	8.0	
8-30	604	360	39	66	8.1	
9-7	569	341	55	94	8.2	2,970
9-14	549	313	82	146	7.8	
9-20	521	319	104	168	7.9	
9-27	576	353	118	208	8.1	
10-4	558	349	56	75	8.2	1,000
10-11	649	401	69	98	8.0	
10-18	676	411	29	29	7.8	
10-25	678	403	42	47	8.1	

Appendix Table 50:

Water Quality Analysis for Station CBD-1
in Colusa Basin Study Area
November 1975 Through March 1976

Date	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Monthly flow (ac-ft)
11-3	884	515	56	70	2,370
11-10	745	455	34	48	
11-17	767	476	65	111	
11-24	726	448	38	57	
12-1	644	374	24	39	1,240
12-8	652	387	30	30	
12-15	883	524	21	21	
12-23	1,003	578	25	29	
12-29	1,043	612	34	25	
1-5	1,064	650	14	15	1,550
1-12	1,064	646	25	35	
1-19	1,157	717	35	53	
1-26	1,020	630	25	25	
2-2	1,064	657	47	55	870
2-9	1,000	609	18	17	
2-17	981	593	30	30	
2-24	927	571	33	37	
3-1	470	292	72	99	2,449
3-8	398	265	140	137	
3-15	481	308	74	102	
3-22	510	327	60	79	
3-30	421	267	72	96	

Appendix Table 51:

Water Quality Analysis for Station CBD-1
in Colusa Basin Study Area
November 1976 Through March 1977

Date	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	pH	Monthly flow (ac-ft)
11-1	704	434	26	27	7.2	900
11-8	708	428	26	25	8.5	
11-15	718	427	34	39	8.6	
11-22	694	428	35	33	7.9	
11-29	735	447	22	22	8.1	620
12-6	794	493	27	25	8.1	
12-13	753	460	21	18	8.1	
12-20	789	477	20	12	8.8	
12-28	971	593	5	6	8.3	
1-3	1,049	621	44	43	8.3	930
1-10	962	575	33	26	8.3	
1-17	1,095	653	26	26	8.3	
1-24	1,220	702	38	48	8.4	
1-31	981	585	31	26	8.5	
2-7	1,085	647	32	32	7.9	448
2-14	1,186	719	26	32	8.4	
2-22	926	544	33	42	8.5	
2-28	790	488	46	66	7.8	
3-7	859	515	35	45	7.9	1,240
3-14	532	327	56	71	8.2	
3-21	516	320	56	66	8.0	
3-29	714	434	44	57	8.5	

Appendix Table 52:

Detailed Water Quality Analysis for Stations on Colusa Basin Drain in Colusa Basin Study Area

1976-1977

Date	EC (μmhos/cm)	Na	Ca	Mg	K	HCO$_3$	Cl	SO$_4$	Total N	Organic N	NH$_4$-N	NO$_3$-N	NO$_2$-N	BOD	pH
					meq/ℓ						ppm				
CBD-4 at Princeton Rd. (D-15)															
6-7-76	397	0.90	1.30	1.85	0.02	3.65	0.13	0.41	2.273	2.08	0.02	0.168	0.005	1.2	8.3
9-7-76	413	0.90	1.50	1.95	0.04	4.18	0.24	0.20	0.870	0.65	0.05	0.164	0.010	0.6	8.2
1-3-77	501	1.50	1.50	1.65	0.08	3.50	0.41	1.19	5.744	3.88	0.42	1.400	0.044	3.6	8.0
CBD-3 at Colusa Bridge (D-12)															
6-7-76	849	4.20	1.50	2.40	0.04	3.76	1.73	2.60	2.350	1.67	0.33	0.320	0.030	0.6	8.4
9-7-76	535	2.25	1.40	1.65	0.06	4.02	0.80	1.05	0.679	0.52	0.08	0.152	0.007	3.0	8.2
1-3-77	1129	6.30	1.80	3.10	0.10	4.07	2.32	4.30	2.842	1.76	0.24	0.825	0.017	7.2	8.1
CBD-2 at Davis Weir (D-13)															
6-7-76	919	4.90	1.30	2.30	0.05	3.86	1.96	3.20	0.930	0.26	0.44	0.204	0.026	2.4	8.4
9-7-76	548	2.55	1.35	1.75	0.06	4.23	0.86	0.88	0.964	0.70	0.10	0.152	0.012	0.6	8.3
1-3-77	1257	7.20	2.00	3.10	0.12	4.07	2.94	5.20	3.783	2.38	0.42	0.960	0.023	10.8	8.1
CBD-1 at Road 99E and Road 108															
6-7-76	945	5.20	1.70	2.70	0.06	4.59	1.96	2.90	1.602	0.83	0.57	0.184	0.018	7.8	8.5
9-7-76	569	2.55	1.40	1.75	0.07	4.18	0.91	1.08	0.710	0.41	0.09	0.196	0.014	0.6	8.2
1-3-77	1049	5.80	2.00	3.10	0.10	4.91	2.04	3.70	1.592	1.11	0.09	0.384	0.008	2.4	8.3